Industrial QUALITY CONTROL

VOL. IV SEPTEMBER, 1947 NO. 2

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Industrial Quality Control

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QUALITY CONTROL IN THE CHEMICAL INDUSTRY

IV: Statistical Methods in Plastics Research and Development

W. L. GORE

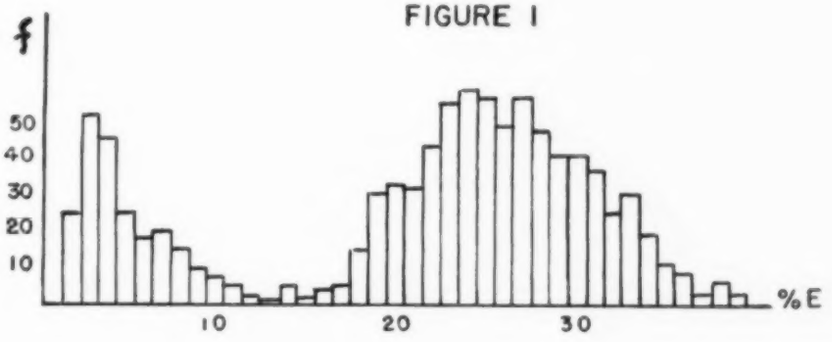
E. I. DU PONT DE NEMOURS AND COMPANY, INC.
PLASTICS DEPARTMENT

Modern statistical methods have become an important factor in all scientific work. This is not surprising since the philosophy of the statistical concept is identical with the philosophy of the scientific method, and the quantitative applications of the scientific method involve an estimation of the probability that a particular set of observations is a result of chance fluctuations rather than the verification of an hypothesis held by the experimenter. In these applications where an hypothesis is to be tested by experimental results, or where it is required to estimate a physical or chemical value (parameter) from experimental results, statistical mathematics quantifies the analysis of the data so that greater assurance can be attached to the conclusions.

In the field of experimental designs a background of statistical methods is of very great value. Poorly designed experiments (in the statistical sense) are the rule rather than the exception where non-statistical workers are dealing with multiple variable phenomena. The rule-of-thumb convention of holding everything constant at some fixed set of conditions and changing only one variable at a time is hopelessly inadequate in many, if not most, of these more complex problems.

The use of statistical methods in plastics research and development has involved a diversified range of techniques with but little intensive use of any particular one (except fiducial limits of reliability with test data). It is the purpose of this paper to describe a few such applications rather than to enlarge upon the statistical principles involved.

FIGURE 1



I. Toughness of Injection Molded Nylon

The use of nylon (hexamethylene diamine adipamide, a super polyamide) for the injection molding* of consumers' items such as combs, tumblers, and gears is new within the last few years. Nylon, besides being hard, heat-resistant, rigid, and having good flow properties for injection molding, is particularly notable for its toughness. Toughness is measured by the area under a stress-strain curve in tensile or flexural stress testing. This toughness is a result of the behavior of nylon when it is stressed beyond its yield point. Most materials are brittle and break at their ultimate stress, but the very long molecules (comparatively) of nylon resist rupture at any particular point and slide over each other so that they become oriented or aligned along the axis of strain. Thus a nylon test piece will elongate a considerable amount before breaking. However, it has been found that under particular conditions of molding, nylon is not consistently tough. Figure 1 shows a distribution of percent elongation (at break) results of nylon test bars subjected to a tensile stress test.

The results plotted on this chart indicate that there are two kinds of nylon bars — tough bars and brittle bars. It was desired to study the causes of this erratic brittleness in nylon, and since the tensile stress test was slow and expensive, a simpler test was devised. This test, called the mandrel bend test, consisted merely in bending a test bar ½ inch wide, 5 inches long, and ⅛ inch thick around a man-

*In the injection molding process for the fabrication of molded articles, a thermoplastic material is melted or softened in a heated cylinder and then injected into a mold by thrusting a piston into the cylinder. The molds used are split so they may be easily opened to remove the molding which sets on cooling. Injection molding machines are automatically operated, and are an important mass production machine for molded articles.

drel ¼ inch in diameter. If there was a brittle spot in the portion of the bar stressed as it was bent around the mandrel, the bar would break. Each 5-inch test bar could be tested in five different spots. It was questioned whether the brittleness was randomly distributed throughout a set of test bars molded under similar conditions from the same batch of nylon molding powder, or if the brittleness was concentrated in particular test bars. Accordingly, a test was made in which each of 280 bars was bent in five places, and a tabulation made as to whether the bar broke in 0, 1, 2, 3, 4 or 5 places. These results are shown in Table I.

Table I

Breaks Per Bar	Number of Bars	Expected Number of Bars With Random Brittleness	Value of Difference for Chi-square
0	157	130.2	5.5
1	69	107.7	13.9
2	35	35.7	0.0
3	17	5.9	
4	1	0.5	24.8
5	1	0.0	
		Total (with three degrees of freedom)	44.2

The expected number of bars in each classification was calculated from the binomial probability where 0.858 of the bends do not break and 0.142 of the bends result in breaks. A total of (280)(5) = 1400 bends were made. Of these, (0) (157) + (1) (169) + (2) (35) + (3)(17) + (4)(1) + (1)(1) = 199 bends produced breaks. On the hypothesis that each place a bend is made is equally likely to produce a break, the observed probability that a bend will produce a break is 199/1400 = .142. Therefore, the third column of Table I shows, to the nearest tenth, the terms of $280(.858 + .142)^5$.

Each entry in the last column is calculated from the relation:

(divergence from expected frequency)^2 ÷ (expected frequency)

Thus, the first value in the table is:

$(157 - 130.2)^2 / 130.2 = 5.5$.

The chi-square value required for testing the probability of the agreement between the observed and expected frequencies shown in Table I is obtained by adding the entries in the last column of the table. Small frequencies are not reliable in making chi-square tests. It is customary in such cases to lump together these small frequencies so as to have all cell frequencies 5 or greater. Accordingly, the last three cell frequencies are combined as shown in the table. Although chi-square is the sum of four numbers, an independent choice of only three of them is possible, since knowing the total frequency (280) and the total chi-square, any one of the four chi-square components can be calculated if the values of the other three are given.* It is conventional to describe this restriction by saying that the chi-square here is based on "three degrees of freedom." Reference to a table of chi-square probability integrals shows that a value of 44.2 with three degrees of freedom can be expected to occur by chance less than once in a million times.** Such an improbable value makes untenable the hypothesis that the brittle spots are distributed randomly.

This finding had two important aspects. One is a characterization of the brittleness phenomena. Brittle material is injected into the moldings in slugs, so that occasionally a molding will have a high concentration of brittle material. The other result of the finding was to re-evaluate the precision of mandrel bend tests. If twenty bars were tested in five places on each bar, previous practice had been to rate the precision of the percent of tough bends as based on 100 independent trials ($\text{sigma} = 100\sqrt{pq/N}$ %, where p = fraction of bends which are tough and q = 1 − p). Since such tests are biased, owing to the fact that a bar which breaks in one place is likely to break in other places, it was necessary to classify test **bars** as tough or brittle rather than to classify **bends** as tough or brittle. Any break within the five bends made on a bar classified that bar as brittle. Thus 100 bars must be tested to give a precision equivalent to that which had been expected originally from 20 bars. A portion of this loss was regained when testing a brittleness concentration below that of the material tested for Table I because of the greater statistical efficiency due to the increased severity of the **bar** toughness rating as compared to the **bend** toughness rating.

Having developed a method of measurement for the occurrence of brittleness in nylon moldings, it was a straightforward problem to evaluate the effect of injection molding variables on brittleness. Factorial experiments were designed and carried out, the data were analyzed by analysis of variance and partial regression techniques, and the following conclusions were reached.

1. Subjecting nylon to high temperatures for long periods causes chemical reactions (possibly the formation of branched chain molecules) which produce a brittle material. Therefore, injection molding of nylon should be carried out with short heating cycles, at low temperatures, and with a minimum amount of material held up in the injection cylinder.
2. The toughness of nylon moldings is increased if the molten material is quenched by injecting it into a cold mold. This effect is believed to be due to the formation of fewer crystalline bonds when nylon is cooled quickly than when it is cooled slowly. Crystalline bonds inhibit the movement of molecules relative to each other.

One of the unit experiments on toughness effects is shown in Table II. The analysis of such data did not follow conventional analysis of variance procedures, since chi-square tests rather than "F" tests were used. Contingency tables

*It may also be argued that, since the fraction breaking (.142) of the 1900 tests was used in calculating the expected frequencies, the degrees of freedom are reduced to 2.

**Table for Statisticians and Biometricians by Pearson.

were made up by combining values in a scheme similar to that employed in analysis of variance techniques. Interactions were tested on the hypothesis of no interaction by accumulating the chi-square divergences of each test from the expected value obtained by correcting it for interaction. The details of the calculations are described in what follows.

For injection temperature and injection cycle variables, Table II can be condensed as shown in Table II-A.

To test for significance, these totals are set up in a **contingency table.***

On the hypothesis of no effect of cycle, the estimate of the number brittle when 400 are tested is (254/800)(400) = 127, and the estimate of the number tough is 400 − 127 = 273. These expected frequencies on the basis of the "null" hypothesis are shown in parentheses in the above table. The chi-square value is obtained from these differences between the observed frequencies in the four cells and those calculated on the hypothesis of no cycle effect. Thus

$$\text{chi-square} = (127-77)^2/127 + (127-177)^2/127 + (273-323)^2/273 + (273-223)^2/273 = 30.3$$

This chi-square value was derived from only one degree of freedom (the difference between 30-second and 90-second cycles). The one percent value of chi-square with one degree of freedom is 6.6 and, since this value is exceeded by the test, the probability that the toughness of the molded nylon bars is not affected by the injection cycle is too small (less than 0.01) to make such an assertion tenable; it is more reasonable to accept instead the hypothesis that the injection cycle does effect the toughness.

A similar calculation between the 450°F injection temperature (353/400 tough) and the 530°F injection temperature (223/400 tough) gives a chi-square of 104 which similarly indicates a significant effect of injection temperature on the toughness of nylon moldings.

The interaction effect of injection temperature-cycle can also be calculated. These calculations are shown in the **interaction residuals** table on this page.

*See "Statistical Methods for Research Workers" by R. A. Fisher, page 83 seq.

TABLE II

Toughness of Injection Molded Type 2* Nylon Bars

Injection Cycle	450°F Injection Temperature		530°F Injection Temperature	
	45°F Mold	250°F Mold	45°F Mold	250°F Mold
30 sec.	90/100 tough	75/100 tough	48/100 tough	40/100 tough
90 sec.	98/100 tough	90/100 tough	70/100 tough	65/100 tough

*This type of nylon was found to be unsuitable for use in injection molding.

TABLE II-A

Injection Temperature

Injection Cycle	450°F	530°F	Totals
30 sec.	a. 188/200	b. 135/200	323/400
90 sec.	c. 165/200	d. 88/200	253/400
Totals	353/400	223/400	576/400

Effect of injection cycle:
30 sec: a + b = 323/400; 90 sec: c + d = 253/400.

CONTINGENCY TABLE

	No. Brittle	No. Tough	Total
30 sec. cycle	77 (127)	323 (273)	400
90 sec. cycle	177 (127)	223 (273)	400
Total	254	546	800

INTERACTION RESIDUALS

cell a.	188/200 − 353/400 − 323/400 + 576/800 = −6/200
cell b.	135/200 − 223/400 − 323/400 + 576/800 = +6/200
cell c.	165/200 − 353/400 − 253/400 + 576/800 = +6/200
cell d.	88/200 − 223/400 − 253/400 + 576/800 = −6/200

On the hypothesis of no interaction, these residuals should be zero. However, this hypothesis can not be tested, because any interaction residual whatsoever would be significant. However, the frequencies in the a, b, c, and d cells of Table II-A may be corrected for the interaction residuals, which gives the following contingency table where the frequencies corrected for interaction are given in parentheses.

The chi-square value is now calculated:

$$\text{chi-square} = (188-194)^2/194 + (135-129)^2/129 + (165-159)^2/159 + (88-94)^2/94 = 1.07$$

This is not significant with the one degree of freedom available for the test. (There are three differences between the four values in the table. One difference is due to injection temperature, one to injection cycle, and one to interaction of temperature-cycle).

NUMBER OF TOUGH BARS OUT OF 200

Injection Cycle	450°F Injection Temperature	530°F Injection Temperature
30 sec.	188 (194)	135 (129)
90 sec.	165 (159)	88 (94)

The complete analysis of Table II yields the following summary:

Source of Variation	chi-square	Degrees of Freedom	Variable Effect
Injection temperature	104.7	1	Significant
Injection cycle	30.3	1	Significant
Mold temperature	8.0	1	Significant
Inj. temp.—cycle interaction	1.0	1	Not significant
Inj. temp.—mold temp. interaction	0.2	1	Not significant
Cycle-mold temp.—inj. temp interaction	0.03	1	Not significant

II. Safety Glass Testing

The standard procedure for testing safety glass consists in dropping a half-pound iron ball from various heights so that it strikes the center of a 12-inch square of safety glass supported at the edges by a frame. If the ball is not stopped by the safety glass sandwich, the test is rated a break or failure, while a glass-plastic sandwich which stops the ball is rated as a non-break or success even though the glass portion of the sandwich is always shattered by the impact. Earlier procedure had involved varying the height of drop and estimating roughly the height of drop giving 50 percent breaks. The results of such tests were used for quality acceptance and as a guide for process variable effects such as type and concentration of plasticizer in the resin placed between the two sheets of glass. In order to obtain a more quantitative estimate of the average height of drop (or approximately the height giving 50 percent breaks), a "run down" test was made by successively testing 40 sheets at 3-foot intervals of drop height, covering the range from the height of drop where all 40 sheets tested were broken to the height where none of the 40 sheets broke. These data are tabulated in Table III.

The "average height" of drops and standard deviation in critical heights to break the sheets have been calculated from these data by forming a distribution where the change in fraction breaking between two heights is considered to be centered about the midpoint of the two heights.* It was decided that the standard deviation from a series of such tests was representative of all safety glass drop tests and that the value was sufficiently precise for use in calculating the average height from a test at some chosen height close to the height giving 50 percent breaks.

This calculation involved a probit transformation** and assumed the distribution of breaks versus height of drop to be normal. The formula used was $\bar{X} = X - \sigma t$, where $\bar{X}$ is the average height, σ is 5.6 feet (the "pooled" σ from the series of tests), and t is the probit value in a table of normal integrals corresponding to the fraction of breaks observed at height of drop, X. The validity of the assumptions is largely dependent upon the height of test being close to the 50 percent height (within the 30-70 percent break range). If the test is made at very nearly the height giving 50 percent breaks, the two-sigma reliability of the average height is given by:

$$\pm 2\sigma_{\bar{x}} = \pm [2(1.25)\sigma] / \sqrt{N}$$
$$= \pm 14.0/\sqrt{N},$$

where N is the number of plates tested. The standard error of $\bar{X}$ is given by: $\sigma_{\bar{x}} = (\sigma/Z)\sqrt{pq/N}$, where σ is the population standard deviation, N is the number of units tested, Z is the ordinate of the normal curve at the probit value of the point where the test is performed, and $p = 1 - q$ is the fraction of the units tested which fail. If the test is performed at the $\bar{X}$, or 50% break point, $p = q = .5$, $Z = .399$, and the standard error of $\bar{X}$ is:

$$\sigma_{\bar{x}} = (\sigma/.399)\sqrt{(.5)(.5)/N}$$
$$= (1.25\sigma)/\sqrt{N}.$$

The foregoing results were incorporated into a graph for computing the 50 percent, or average height, and a tabulation was made for determining the precision for the number of safety glass sheets tested. Control charts were then set up for routine production testing, and experimental developments are now evaluated by this revised procedure.

*The statistical aspect of this type of data is discussed in a paper entitled "On the Statistics of Sensitivity Data," by B. Epstein and C. W. Churchman, ANNALS OF MATH. STATISTICS, Vol. XV, March, 1944.

**In making a "probit transformation," the value of t in a table of areas under the normal curve is determined which corresponds to the area or fraction in the body of the table. Thus a fraction 0.50 is transformed to a t or probit value of 0.0.

TABLE III

Height of drop	Number of Sheets Tested	Fraction Breaking	Interval Midpoint	f Change in Fraction Breaking	d Dev. from Assumed Mean	fd	fd^2
11 ft.	40	.00		.10	−3	−.30	+.90
14 ft.	40	.10	12.5 ft.	.15	−2	−.30	+.60
17 ft.	40	.25	15.5 ft.	.20	−1	−.20	+.20
20 ft.	40	.45	18.5 ft.	.35	0	0	0
23 ft.	40	.70	21.5 ft.	.20	+1	+.20	+.20
26 ft.	40	.90	24.5 ft.	.10	+2	+.20	+.40
29 ft.	40	1.00	27.5 ft.			$\Sigma fd = -.40$	$\Sigma fd^2 = 2.30$

$$\bar{X} = X_o + c\Sigma fd = 21.5 + 3(-.40) = 20.3 \text{ ft.}$$
$$\sigma_x = c\sqrt{\Sigma fd^2 - (\Sigma fd)^2} = 3\sqrt{2.30 - (-.40)^2} = 4.40 \text{ ft.}$$

On Simple Correlation*

H. J. O'CONNOR

DEVELOPMENT DIVISION, UNION CARBIDE & CARBON RESEARCH LABS., INC.

In "The Grammar of Science" Karl Pearson says, "The scientific method . . . consists in the careful and laborious classification of facts, in the comparison of their relationship and sequences, and finally in the discovery, by the aid of disciplined imagination, of a brief statement or formula, which in a few words resumes a wide range of facts. Such a formula . . . is termed a scientific law."

Statistical techniques offer a tool that **aids** in the discovery and measurement of these quantitative relationships. This tool is called correlation. It is generally agreed that correlation is a large topic. Hence, in this discussion, we shall only skirmish the idea, restricting ourselves to the philosophy of the easiest but important case of simple linear correlation. Indeed, we shall be easy on ourselves by selecting examples that require short calculations.

We shall begin with a brief statistical review which is important for what we shall have to say in the sequel. We might call it "a bit of the sampling problem." We review this topic in order to keep from becoming merely manipulative and perhaps somewhat ridiculous.

The fundamental notion in statistical theory is that of the total aggregate . . . the population, or universe. This term designates any collection of measurements under consideration; for example,

(1) the **population** of the heights of all men;

(2) the **population** of the percent carbon of all steel of a certain grade;

(3) the **population** of all correspondences of heights of fathers versus the heights of sons;

(4) the **population** of all correspondences of amount of money earned versus the amount of money paid in income tax.

*A talk given at a meeting of the Buffalo Section, American Society for Quality Control, February 24, 1947.

Theoretically, many populations may be considered as if they had an infinite number of members. In any case, unless we have all the members of a population on hand, we must consider the data to be but a **sample** from the population. Whatever observations we make, therefore, are made on a **sample.** An important part of statistical science consists of attempting to draw valid inferences about a given population from information supplied by samples from this universe.

Most of us have had some experience with the behavior of samples. Consider, for instance, the average and standard deviation. Suppose we have on hand a normal population with average 20 and standard deviation 2. Take a random sample from this population and let $\bar{X}_1$ and σ_1 be the average and standard deviation of the **sample.** We know from experience that the chances of $\bar{X}_1$ equaling 20 and σ_1 equaling 2 are small, and that as sample size increases, the probability of deviations from these expected values by more than a negligible amount decreases. The variations of the values of sample statistics ($\bar{X}_1$ and σ_1) from the population values (20 and 2) are called **sampling fluctuations.** We expect and allow for these variations in control chart work when we place upper and lower limits on the values of sample averages and standard deviations. When a point goes out of limits on the chart we describe it as "out of control," meaning that the variation in the sample is too great for us to accept the thesis that it came from the original population. Let us now proceed with this philosophy in mind.

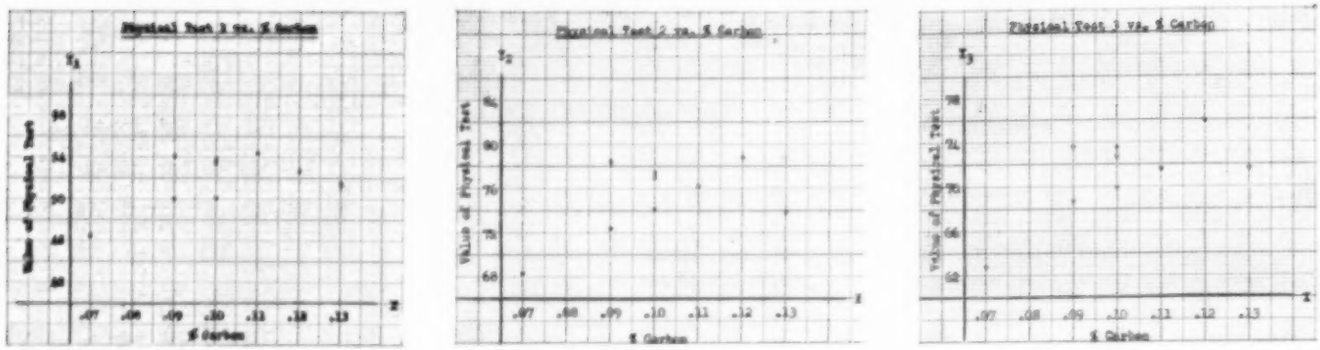
Consider an example. A metallurgist has nine steel bars. The carbon content of these bars ranges from .07% to .13%. Statistically, this means that he has on hand a sample of size nine from a theoretically infinite population of such steel bars. The metallurgist subjects these steels to three physical tests which we shall designate as Test 1, Test 2, and Test 3. Table I gives a tabulation of his results, with the percent carbon arranged in order of size to facilitate a preliminary visual survey of the data.

The metallurgist would like to answers two questions: (1) Are the values for the physical tests significantly affected by the carbon content of the steels (is there significant correlation?) (2) Might it

Table I

	X Percent Carbon	Y_1 Test 1	Y_2 Test 2	Y_3 Test 3
	.07	46.5	68.4	62.8
	.09	54.1	78.4	73.5
	.09	50.0	72.4	68.7
	.10	53.4	77.4	73.5
	.10	53.8	77.1	72.7
	.10	50.1	74.2	69.9
	.11	54.4	76.2	71.6
	.12	52.7	78.9	75.9
	.13	51.5	73.9	71.6
N =	9	9	9	9
Sum =	.91	466.5	676.9	640.2
Average =	.1011	51.8333	75.2111	71.1333
Sum of Squares =	.0945	24233.97	51000.55	45653.26
σ =	.0167	2.4438	3.1651	3.5550
$(\Sigma XY)/N - \bar{X}\bar{Y}$ =		5.261889	7.631889	7.322889
r =		+.53	+.53	+.70

FIGURE 1 — SCATTER DIAGRAMS FOR TABLE I



be possible to predict the value for a test from the carbon content of the steel?

He looks at the data and shows no great joy. However, he feels that because the data cost money and time he will subject them to some objective test. He plots the data as shown in Figure 1.

Applying simple linear correlation to these data, he proceeds by assuming that if any relationship exists between Y and X it will be represented by a straight line. Now any sloping straight line he happens to draw through these data will have an equation of the form

$$Y = a + bX$$

where

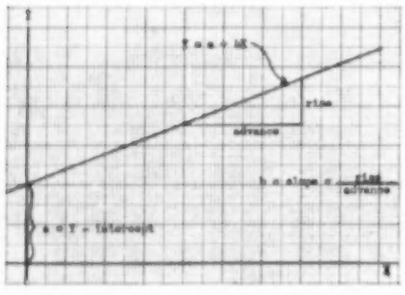
a = Y — intercept

and

b = slope of the line.

Figure 2 illustrates these concepts.

FIGURE 2



He can draw a line through the data in many ways; for instance, he may do it by "jockeying" a transparent ruler until he thinks he "has it," or he may use some formulas to calculate the values of **a** and **b**. Here the statisticians have come to his aid; they say that the line to put through these points is the "line of regression of Y on X", which is

$$Y_r = a + bX$$

with **a** and **b** calculated from the two equations

$$Na + b(\Sigma X) = \Sigma Y$$
$$a(\Sigma X) + b(\Sigma X^2) = \Sigma XY,$$

where

N = the number of items,

ΣX = the sum of the X-values,

ΣY = the sum of the Y-values,

ΣX^2 = the sum of the squares of X-values,

ΣXY = the sum of the products, X times Y.

The values of **a** and **b** thus obtained are the ones that result when the sum of the squares of the vertical distances from the plotted data to the line is minimized. The line determined by this method is often called "the line of best fit."

The metallurgist now has straight lines which he can draw on the graphs. They may not be "worth a hoot", but if they are, he can use them to **estimate** the values for the tests from the percent carbon in the steel. The usefulness of a line of regression for prediction purposes depends upon whether or not the metallurgist is satisfied with such predictions. Of course he will be happier the higher the value of r, which will be explained presently.

Now the question is: "How much does the observed value of Y, for a given value of X, deviate from the value of Y calculated by means of the regression equation?" It is only reasonable to expect that there will exist deviations between observed and computed values, the extent of the deviations depending upon the particular data. The metallurgist will therefore calculate next the standard deviation of the differences between the actual plotted values of Y and the estimated values, Y_r. This number he gets from the formula

$$\sigma_{Ys} = \sqrt{\Sigma(Y - Y_r)^2 / N}$$

where

σ_{Ys} = the "standard error of estimate",

Y = observed value of Y as plotted,

Y_r = value of Y estimated from the line of regression,

N = number of items.

Figure 3 illustrates the deviations we have been considering. For any X the metallurgist estimates Y by reading Y_r from the line. There is a certain "error" in doing this. To get a measure of this error he subtracts each estimated Y, (i.e. the value of Y_r) from the actual plotted Y. These differences are, then, the deviations of estimated values from actual values. He then finds the standard deviation of these errors, which is the number σ_{Ys}, i.e., the standard error of estimate. This standard error gives him an average measure of how far the actual values of Y tend to fall away from the line. He can then draw about the regression line 1σ, 2σ, and 3σ bands, as shown in Fig. 4, where each σ means σ_{Ys}.

We are now prepared to introduce a handy number called the correlation coefficient, designated by the letter r. In part of whct follows it will be convenient to use a number called the variance, σ^2, which is the square of a standard deviation.

Up to this point the problem has been to see if any correlation exists between Y and X. **Whether Y is related to X or not, its set of**

FIGURE 3

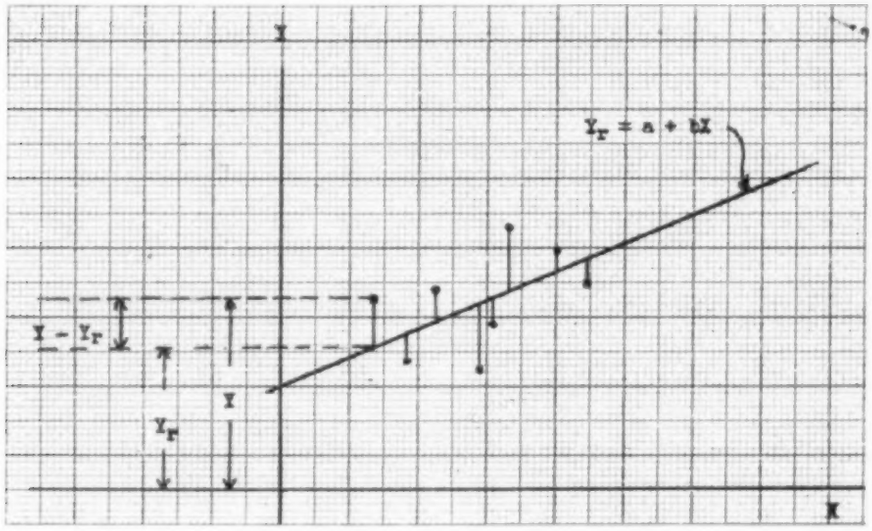
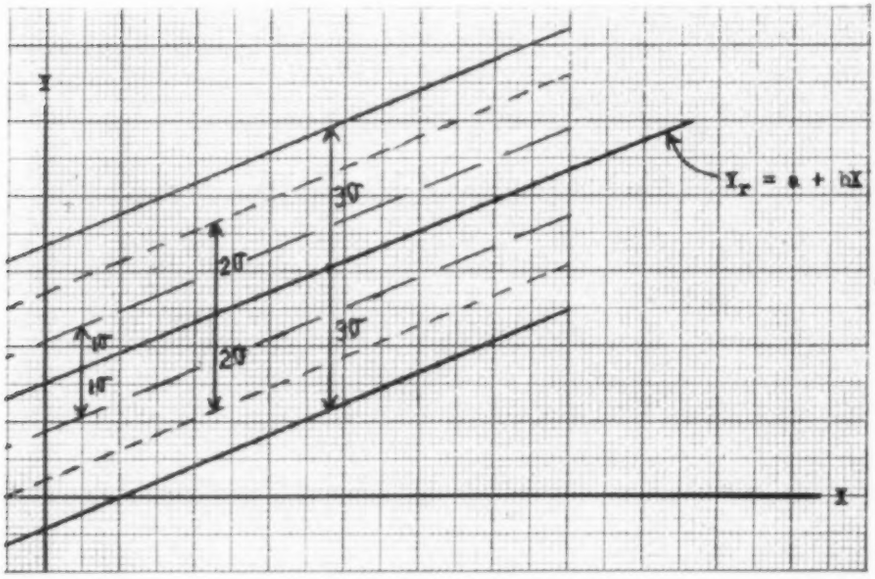


FIGURE 4

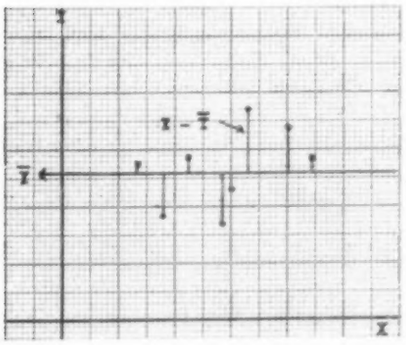


values has a certain variance, namely,

$$\sigma_Y^2 = \Sigma(Y - \overline{Y})^2 / N.$$

Figure 5 pictures deviations of Y about $\overline{Y}$.

FIGURE 5



Next, in correlation, we investigate to see if we can blame any of this variance on the fact that X changes. The formula used is

$$\sigma_{Y_r}^2 = \Sigma(Y_r - \overline{Y})^2 / N.$$

This is the variance that the Y-values have when, instead of taking the actual plotted Y's, we take the Y_r's from the line of regression. Figure 6 pictures these deviations. We note that $\sigma_{Y_r}^2$ = variance of deviation of Y_r from $\overline{Y}$. This is the amount of the total variance, σ_Y^2, that can be blamed on the fact that X changed as Y changed.

Now, of the total variance in Y, (σ_Y^2), there is some left, over and above that due to X,($\sigma_{Y_r}^2$). This left-over variance is that part of Y's variability that X's variability does not account for. It is given by

$$\sigma_{Y_s}^2 = \Sigma(Y - Y_r)^2 / N$$

which is the **square** of our old friend, the standard error of estimate. (See Fig. 3). We note again that $\sigma_{Y_s}^2$ = variance of deviations of actual Y's from estimated Y's. We observe also that this measures the variance that Y has beyond any amount that can be assigned to X.

It can be verified that

$$\sigma_Y^2 = \sigma_{Y_r}^2 + \sigma_{Y_s}^2.$$

This makes sense, for it says, "The total variance, σ_Y^2, of a set values equals a certain amount of variance, $\sigma_{Y_r}^2$, that can be explained by the fact that Y depends on another variable, plus a left-over amount of variance, $\sigma_{Y_s}^2$, that is unexplained."

The relationship can be characterized pictorially as in Figure 7.

Now, let us consider the quantity

$$r^2 = \sigma_{Y_r}^2 / \sigma_Y^2,$$

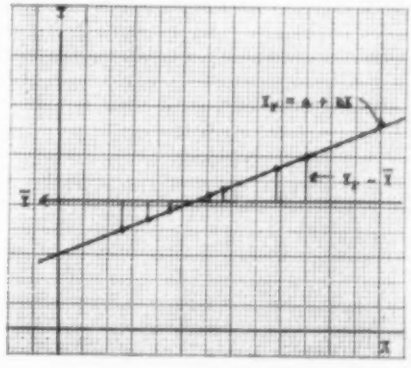
i.e., that part of Y's variance due to its correlation with X, divided by the total Y-variance; or, r^2 is the proportion of the total Y-variance that can be blamed on X. It is called the coefficient of determination. We note that r^2 cannot be greater than 1. The square root of r^2, namely r, is called the correlation coefficient. If all the points lie on a straight line, r is equal to 1 or -1, and conversely.

The preceding discussion has not involved very much numerical work. The reason for this is that the regression equation and correlation coefficient are not generally expressed in the above forms. They are quite often expressed as follows:

Line of regression of Y on X:

$$Y - \overline{Y} = r(\sigma_Y / \sigma_x)(X - \overline{X}).$$

FIGURE 6



Correlation coefficient:

$$r = \overline{(X\ Y} - \overline{X}\ \overline{Y})/(\sigma_x \sigma_Y).$$

Standard error of estimate:

$$\sigma_{Y \cdot x}^2 = \sigma_Y^2\ (1 - r^2).$$

All the symbols here have been previously explained.

In the early part of our discussion we said we would not forget that any data we might have is but a sample from a population consisting of an infinite number of such things. We agreed to be on the alert for sampling fluctuations. Let us try to make this situation more precise.

(1) Theoretically, at least, we have a population consisting of an infinite number of sets of corresponding values of Y and X.

(2) This population has some correlation coefficient, but we don't know what it is. However, call it ϱ. (Greek letter "rho").

(3) We take a sample from the population. We calculate the correlation coefficient, r, of this sample. We cannot expect this r to be equal to ϱ, any more than we can expect the average and standard deviation of samples to be equal to the average and standard deviation of the population.

(4) We may, however, expect the correlation coefficients of samples to display some pattern of average behavior just as we know that averages and standard deviations of samples do (recall the limits set on control charts).

(5) We shall not go into the general problem of the behavior of correlation coefficients of samples, but we do seek some kind of answer to two important questions, which we shall discuss under A and B as follows.

(A) Consider the case where the population correlation coefficient is zero. How do the correlation coefficients of samples from this population behave? Shewhart in his "Economic Control of Quality of Manufactured Products" records an experiment in which eight samples of size five were drawn from a population whose correlation coefficient, ϱ, was known to be zero. Here are the sample values of r he obtained: −.82, −.60, −.21, +.04, +.23, +.30, +.42, +.76. This really gives one meat for thought! Our first question is, therefore, "Given a sample with correlation coefficient r, **how does one know if there is any correlation at all in the population from which the sample was taken?**" Statisticians have helped us here. The question can be answered by reference to a table or, in case the sample is of size N⩾50, to a short formula. Table II provides for sample sizes from three to fifteen. (A much more complete table is available in Fisher's "Statistical Method For Research Workers", and should be used in actual practice.)

FIGURE 7

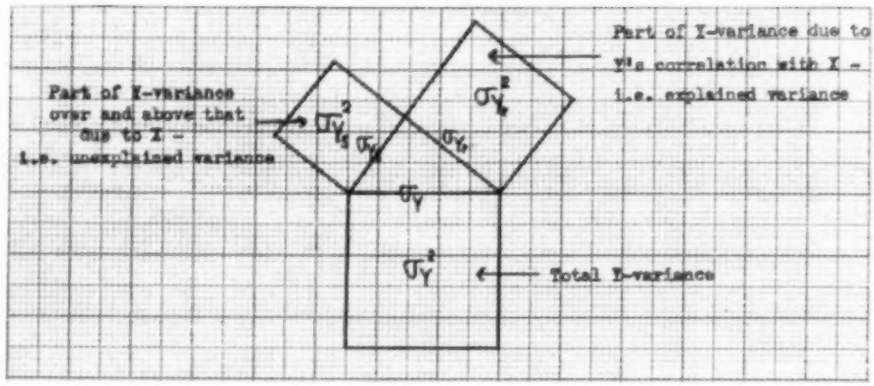

Part of Y-variance due to Y's correlation with X - i.e. explained variance
Part of Y-variance over and above that due to X - i.e. unexplained variance
Total Y-variance

Table II

Sample Size	P = .05	P = .01
3	.997	.9999
4	.95	.99
5	.88	.96
6	.81	.92
7	.75	.87
8	.71	.83
9	.67	.80
10	.63	.76
11	.60	.73
12	.58	.71
13	.55	.68
14	.53	.66
15	.51	.64

Consider this table. For a sample of size five, and under P = .05, we read the value .88. What does this mean? Precisely the following: **if** the **population** correlation coefficient is **zero**, and **if** random samples of size five are drawn indefinitely from this population, then, in the long run, we may expect about 5% of these samples to show correlation coefficients greater in numerical value than .88. Now, if an observed sample of size five has a correlation coefficient greater in numerical value than .88, and if the "5% risk" is small enough for our purposes, then we may say that it is quite probable that the sample came from a population having a non-zero correlation coefficient. If we feel that a 5% risk is too great, we may resort to the 1% risk and use the value .96 from the table. Thus we see that the correlation coefficients from the experiment mentioned above in Shewhart show nothing abnormal, and indeed could well have come from a population with correlation coefficient, ϱ, equal to zero.

In case the size of the sample is N⩾50 we can use the expression $1.96/\sqrt{N-1}$ for the 5% risk and $2.56/\sqrt{N-1}$ for the 1% risk, which is the "short formula" referred to earlier.

Now, let us return to our original problem: physical tests vs. carbon in the steel. We recall that Test 1 vs. percent carbon shows a correlation coefficient of r = +.53. With a sample size of nine, and under P = .05 in Table II, the critical value is .67. But .53 is not equal to, nor greater than, .67. Therefore, on the basis of this sample we cannot assume that there is any correlation in the population from which this sample was drawn. In other words, it is indicated that Test 1 and percent carbon are not linearly correlated, and in making this statement we are operating at the 5% risk level. However, if the sample was of size 14 instead of nine, the critical value in the table would be .53, and we would say that it is quite probable that there is correlation between Test 1 and percent carbon. The size of the sample is thus a very important factor.

For Test 2 vs. percent carbon we have the same situation. For Test 3 vs. percent carbon, however, we have r = .70, and hence we may

say that it is quite probable that Test 3 has some correlation with percent carbon. **This does not mean that the population correlation coefficient is high nor does it mean that it is low—the test only indicates that it is quite probable that there is some correlation in the population consisting of the values of Test 3 vs. percent carbon.**

We are now ready to pose our second question.

(B) In the foregoing we have seen that it is indicated statistically that Test 3 vs. percent carbon are correlated, but to what degree we do not know. True, the sample of size nine shows a correlation coefficient of $r=.70$, but it would be folly to expect that the population correlation coefficient, ϱ, is .70. Indeed, ϱ may be greater than .70.

Now a fair question is this: "By reason of the knowledge of the correlation coefficient in this sample, can we compute a lower and upper limit such that the population correlation coefficient, ϱ, lies in this range?" The answer is "No." Can we calculate limits such that the probability is, say .95, that ϱ will lie in the range? No, we cannot, for such a question has no meaning . . . ϱ either lies in the range (in which case the probability is one) or it does not (in which case the probability is zero).

What **can** we do? Given the sample correlation coefficient, r, we can calculate a lower and upper limit at some stated probability level, say .95, and we can think of the population correlation coefficient, ϱ, as lying in this range, if we remember that what is really meant by the ".95" is that in a large number of such samples we may expect 95% of the ranges so calculated to contain the population correlation coefficient ϱ; that is, if in any given case we conclude that ϱ lies in the calculated range, we should expect to be right about 95 times in 100. This range is called a confidence interval for ϱ, and the ".95" is called the confidence coefficient.

The following method for computing these limits is due to R. A. Fisher. We shall illustrate it for the case of the Test 3 vs. percent carbon correlation. Fisher considers the transformation of r to a new variable Z, by means of

$$Z=\tfrac{1}{2}\log_e[(1+r)/(1-r)]$$

or

$$Z=1.15129\log_{10}[(1+r)/(1-r)]$$

or

$$Z=\tanh^{-1}r,$$

all three of which are equivalent. He showed that the distribution of Z is practically normal, with a standard deviation

$$\sigma_Z=1/\sqrt{N-3},$$

where N is the size of the sample. Thus, to determine a confidence interval for ϱ, we first determine a confidence interval for Z, and transform back.

In the Test 3 data we had $r=.70$. This yields a Z of about .87. Now a symmetrical 95% confidence interval for Z is (according to normal theory)

$$Z\pm 1.96\sigma_Z,$$

or, in the case at hand,

$$.87\pm 1.96/\sqrt{9-3}.$$

This gives Z-values equal to .07 and 1.67. Transforming back to correlation coefficients, we find that the confidence interval for ϱ is from about .07 to .93, with a confidence coefficient of .95.

At once we say, "From .07 to .93 is a lot of territory . . . our knowledge is not very definite." This is indeed correct! If we want to narrow the confidence interval we will need to use a larger sample; e.g., $r=.70$ in a sample size of, say 67, yields a confidence interval from about .55 to .81. All of which merely emphasizes the desirability of obtaining as large a sample as is practicable.

Let us stop here; much, very much has been left unsaid, but perhaps this little discussion will encourage further search for more of the "whole story." We shall conclude with three general comments.

(1) The business of causal relationship between Y and X is sometimes a matter of belief . . . does Y cause X or does X cause Y? Practically, we plot "cause" horizontally, call it X, and find the regression of Y on X, and we try to decide this on scientific grounds.

(2) A correlation between two variables may be due to a third cause. For instance, the value of the physical test may be due to the percent manganese in the steel and at the same time the percent carbon may be due to the manganese; i.e., the relation of the physical test and the percent carbon may be due to the one cause, the manganese content.

(3) Finally, the correlation may be an out-and-out accident.

Quality Control in Relation to Time-Study

RAY W. GOOD

ROBERTSHAW THERMOSTAT COMPANY

We feel that one of our best applications of quality control by statistical methods at Robertshaw's is our tie-in with the Time-Study Department. Nearly every repetitive job in our plant is timed and put on an incentive basis. Naturally, this promotes quantity production, but along with this we want quality production, and the answer to this is statistical analysis of each process.

On any new job that is put in any of the production departments, a request is sent by the production foreman to the Time-Study Department, asking for a time study, so that a piece-work rate can be applied. The Time-Study Department requests a Quality Control study, in order to determine whether the

job is ready for timing. We then make an eight (8) hour study on each shift, either variable or percent defective, to determine whether the job is running in control, and if so, whether it is meeting Engineering specifications. (The job cannot be timed until passed by Quality Control). If the job is satisfactory we notify the Time-Study Department so it can proceed with the time-study. We also make a quality control check during the time-study so that we can have a permanent record of the quality produced during time-study. If at any future date the operator should do bad work while working on piece-work, we have a record to show that quality work can be made and still enough parts produced to meet the piece-work rate. When an old job is to be re-timed, we have past data which usually enables us to waive the preliminary check and study the job only during timing.

The procedure as described above has saved us a lot of defective work, as we have found many jobs which were not ready for timing, but required a change in set-up in order to produce in a state of control. Under the old set-up a job of this kind could very easily have been timed and defective parts produced in quantity before corrections were made. It has also enabled us to get Engineering Specifications changed on certain jobs, when we found a process producing to the best of its ability and still not meeting tolerances.

The following charts show examples of studies, both variable and percent defective, which were made either before or during Time-Study.

Figure 1. Before Time-Study—Variable

This variable study was on the milling of a flat on one side of a small brass cylindrical piece. The dimension of .325" ± .001" was taken from the milled flat to the outside diameter of the cylinder. As shown by the chart, this process was in control using .0026" as compared with .002" allowed by our drawing. When measuring this piece we found that whatever variation was on the outside diameter (either large or small), also showed up on the finished milled

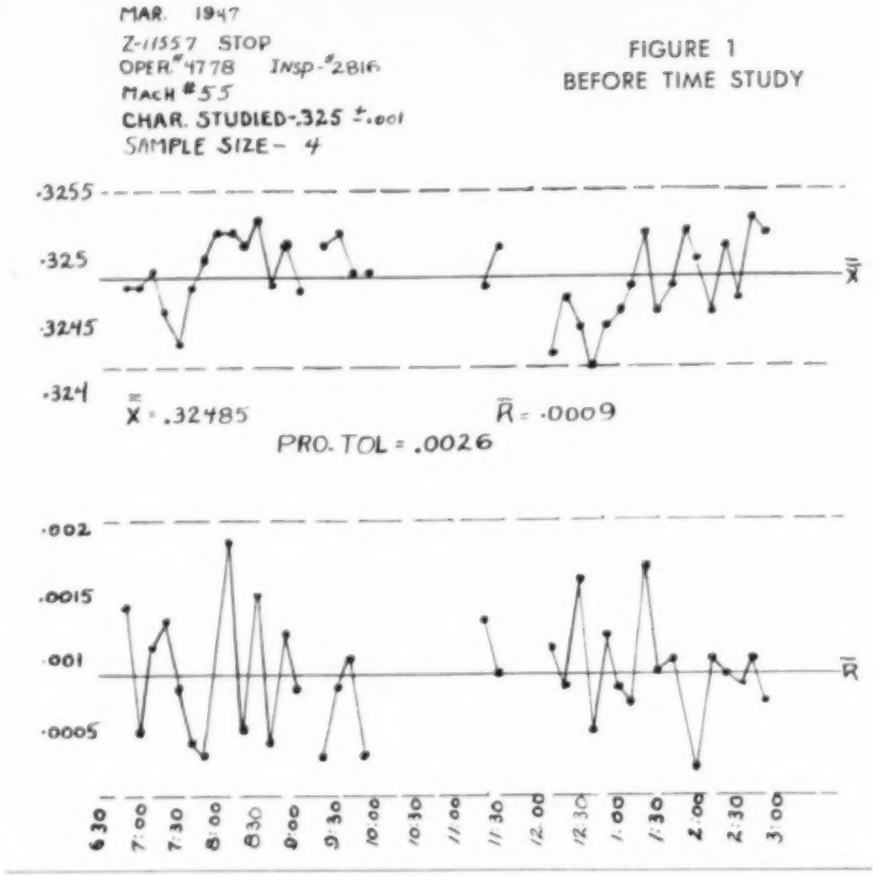
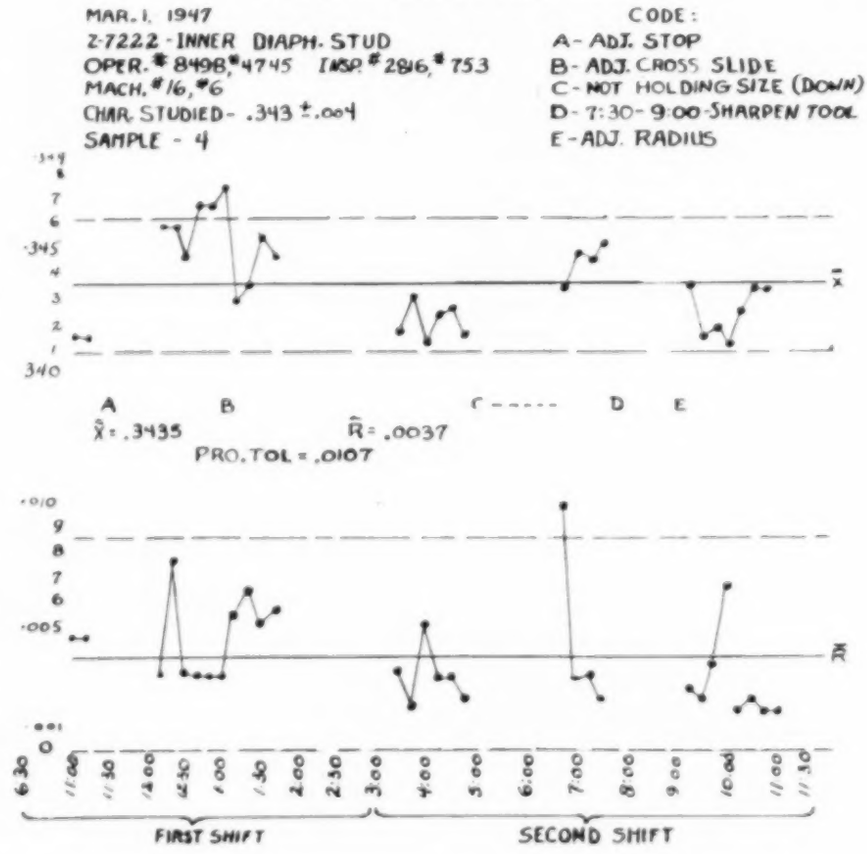


FIGURE 1
BEFORE TIME STUDY

FIGURE 2—DURING TIME STUDY



piece. As the tolerance on the Outside Diameter of the piece was also plus or minus .001", we actually had no tolerance left for our milling operation. The reason for this condition was due to the fixture mastering the piece on the centerline, rather than on the Outside Diameter. Due to the above analysis, the study was rejected, and the information turned over to tool design in order to change the mastering of the piece in the fixture.

Figure 2. During Time-Study—Variable

This operation was the machining of a radius on the end of a stainless steel cylindrical piece. The dimension checked was the length from the radiused end to the flat end of the piece. This study was run for two eight hour shifts. Our chart showed a few points out of control and too wide a range for our drawing tolerance of .343" ± .004". The length variation is mostly dependent on the operator, as this job is done on a Hardinge Lathe with the feed of the cutting tool controlled by the operator. In view of the above, as shown by our variable study, the job was rejected and the Time-Study rate was not applied.

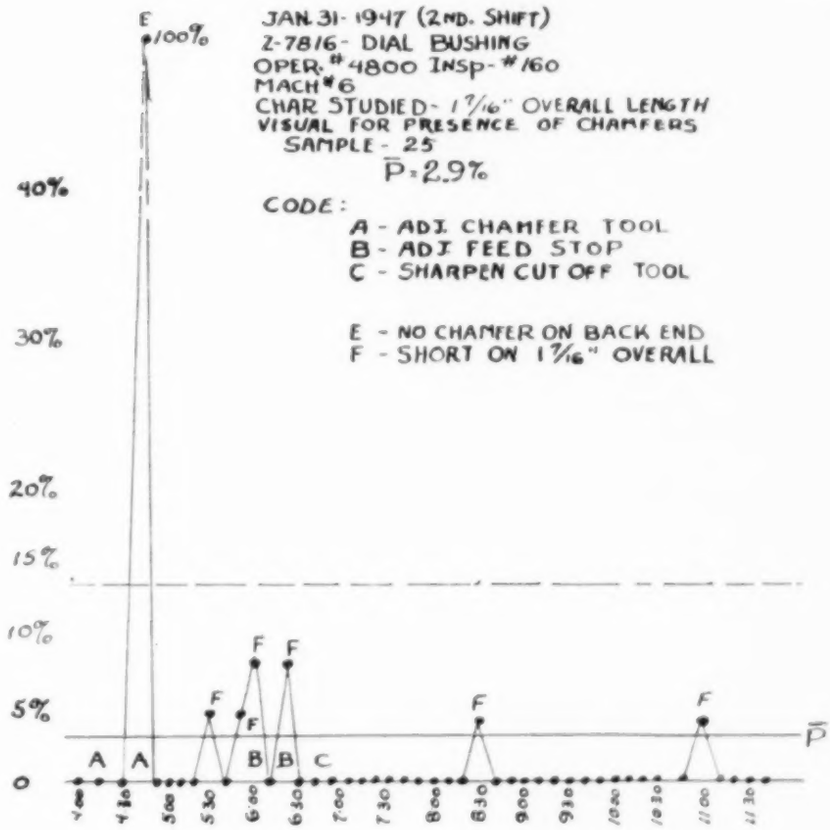
Figure 3. Before Time-Study—Percent Defective

This operation is the cutting off of certain lengths of bushings from steel tubing, and chamfering the Outside Diameter and Inside Diameter. After analyzing this operation it was found that the short pieces were either the last pieces in the rod, or the next to the last piece. The only correction that can be made on this condition is for the operator to throw out the last two pieces from each rod. It is not always possible for the operator to do this, but enough can be caught to reduce the percent defective to meet our quality requirements.

Figure 4. During Time-Study—Percent Defective

This operation consists of facing, grooving, drilling and tapping a flat rectangular flange plate. After the facing and grooving operation, the grooves must clean up when sanded lightly. This indicates that they are level with the rest of the

FIGURE 3—BEFORE TIME STUDY



DURING TIME STUDY

FIGURE 4

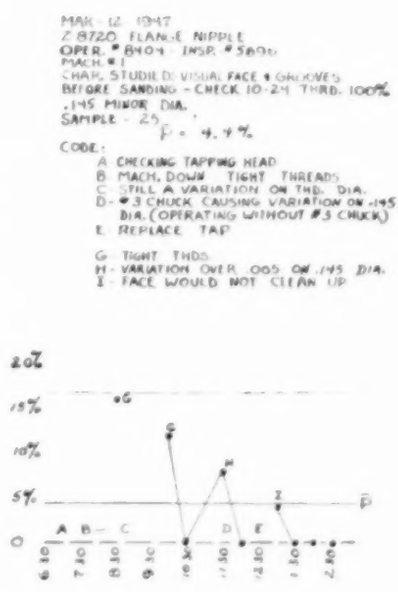

MAR. 12 1947
Z 8720 FLANGE NIPPLE
OPER. # 8404 INSP. # 5890
MACH. # 1
CHAR. STUDIED: VISUAL FACE & GROOVES
BEFORE SANDING - CHECK 10-24 THRD. 100%
.145 MINOR DIA.
SAMPLE - 25
P̄ = 4.9%
CODE:
A CHECKING TAPPING HEAD
B MACH. DOWN TIGHT THREADS
C STILL A VARIATION ON THD. DIA.
D - #3 CHUCK CAUSING VARIATION ON .145 DIA. (OPERATING WITHOUT #3 CHUCK)
E REPLACE TAP
G TIGHT THDS.
H - VARIATION OVER .005 ON .145 DIA.
I - FACE WOULD NOT CLEAN UP
20%
15%
10%
5%
0
A B C D E
P̄

FIGURE 6

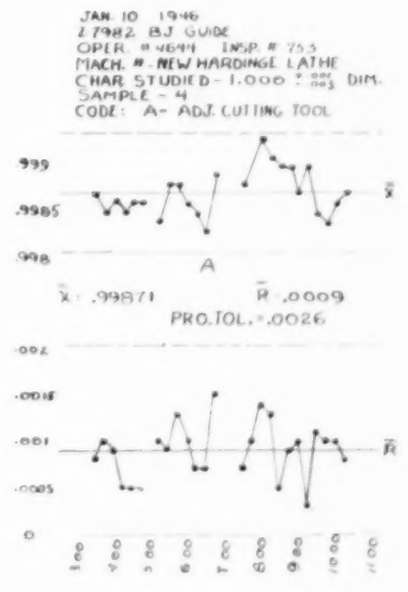


plate. As noted by the chart, there was considerable downtime plus undersize threads and uneven faces. The average percent defective was 4.4% which was higher than our acceptable quality level. Therefore, the Time-Study was rejected.

Figure 5. During Time-Study—Percent Defective

This chart shows an operation which was very good, and on the basis of this eight (8) hour check we passed this Time-Study.

Figure 6. During Time-Study—Variable

This operation is the turning of a 1.000" + .001"-.003" diameter on a Hardinge Lathe. The process was in control, and a tolerance of .0026" was used as compared with a drawing tolerance of .004". This job was passed for Time-Study.

FIGURE 5—DURING TIME STUDY

JAN 31, 1947
Z-7812 SLEEVE
OPER. # 7193 - INSP # 2816
MACH #6
CHAR. STUDIED - 55/64 OVERALL, VISUAL CHAMFERS
SAMPLE - 25
$\bar{P} = 0$

Engineered Assembly Tolerance

HENRY C. EATON

AMERICAN BOSCH CORPORATION

One of the fallacies in a good many engineering design offices and drafting rooms is the old-fashioned method of adding all the tolerances on a number of component parts to obtain the total tolerance for the complete assembly. Statistically, the chances are very slight that all the component parts in an assembly would be made to their maximum dimension, and hence would need the maximum assembly tolerance. Therefore, it would seem that in the majority of cases, if not all, there is a waste of tolerance on an assembly that could well be reduced.

The quality control engineer has several methods of determining variations, and one of these, the root mean square, can be applied very nicely in figuring an engineered assembly tolerance.

Here is how to use this simple quality control tool:

(1) Square the **total tolerance spread** of each component.

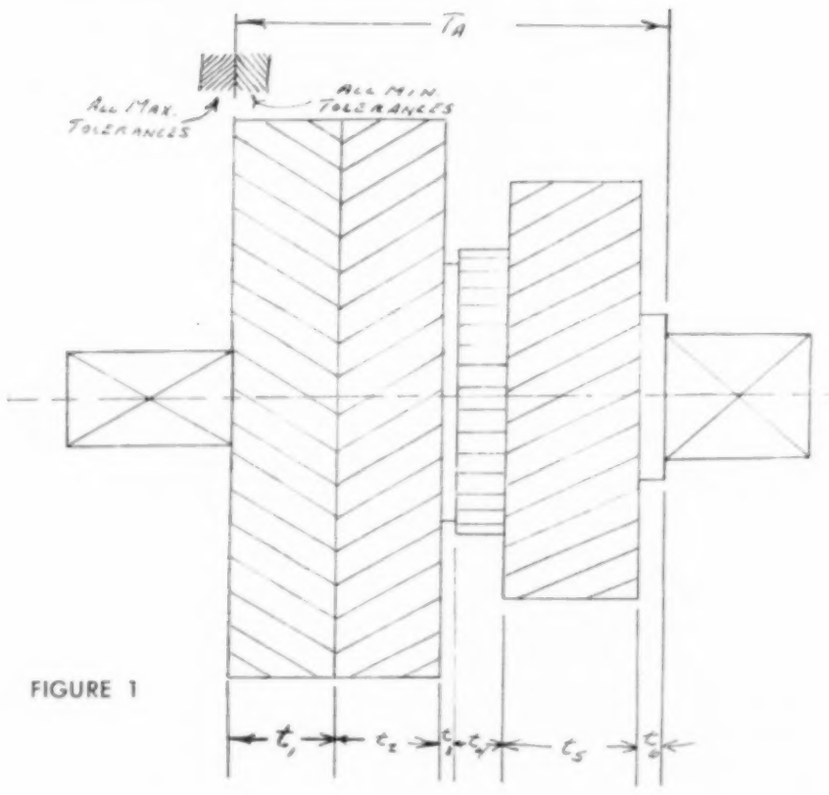


FIGURE 1

(Example: If the specification calls for a tolerance of ± .002" on a component, the **total** tolerance would be .004" and its square would be .000016".)

(2) Add these squared sums.

(3) Extract the square root of the total. This figure will then be the engineered assembly tolerance.

Expressed algebraically these three steps become:

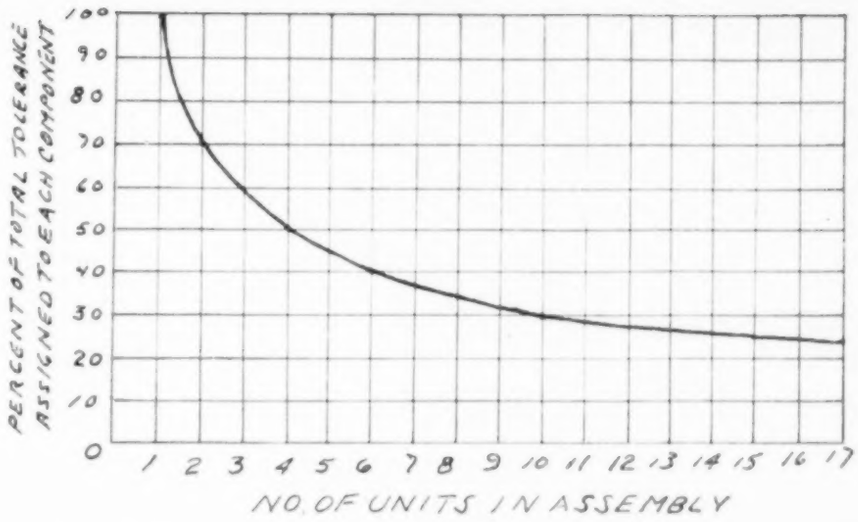
$$T_A = \sqrt{t_1^2 + t_2^2 + t_3^2 \ldots + t_n^2}$$

where T_A = assembly tolerance, and t_1, t_2, etc. = component tolerances.

It must be emphasized, however, that even though the majority of applications involve **mutually independent** component tolerances, there are shop situations in which there is some **correlation** between components; in such cases this formula does not apply.

An example showing the use of the formula is given in Figure 1 where several gears and spacers for a transmission are shown assembled on a shaft preparatory to placing it in a housing. The problem is to make the dimension between the bearings of the housing such that all assemblies of gears will fit between the bearings and yet not have excessive end play. There is shown also, the relative housing dimension figured on all-maximum or all-minimum component dimensions.

FIGURE 2



The chart (Figure 2) gives another approach to the same problem and can be used as a ready reference guide in designing assemblies. The chart is simply a graph of the equation:

$$t\,T = 100/\sqrt{n},$$

where T = a given total tolerance, t = proportion of T to be assigned to each component, and n = the number of components in the assembly. It has been found, however, that this chart applies more accurately to components manufactured under "quality controlled" conditions than it does to components from processes not operating in statistical control.

One should bear in mind the fact that the chart gives the "percent of total tolerance assigned to each component" based on a known assembly tolerance, whereas the equation shown in the first part of this paper gives the overall assembly tolerance based on the known component tolerances. The use of both sections, depending on the case, will result in a more uniform, better-engineered product.

INTENSIVE PROGRAM IN STATISTICAL QUALITY CONTROL AT INTERNATIONAL HARVESTER COMPANY

On Thursday and Friday, August 7 and 8, 1947, the International Harvester Company held a Works Managers Quality Control Conference at its newly acquired Manufacturing Research Building in Chicago, Illinois. The two day conference, devoted to Statistical Quality Control from the viewpoint of top management, was the forerunner of an intensive program by the company.

Messrs. J. L. McCaffrey, President; Levin H. Campbell, Jr., Executive Vice-President; M. C. Evans, Manager of Manufacturing Research; and A. C. Richmond, Supervisor of Inspection Methods, took part in the conference.

During this conference such topics as "Introduction to Statistical Quality Control," "Construction of a Control Chart," "Interpretation of Process Control Charts," "Acceptance Sampling," and "Putting Quality Control to Work" were taken up. Considerable time was devoted to general discussions of the entire quality control area—its value as related to design, specifications, and inspection, as well as to production.

Following this two day Works Managers Conference at Manufacturing Research, a ten day intensive course (August 18th to 29th) in Statistical Quality Control was attended by some seventy selected representatives of the Harvester Company. For the most part, these selected representatives consisted of a Quality Control Engineer and a Director or Assistant Director of Training from each plant. It is expected that these two persons will work as a team in further introducing the uses of Statistical Quality Control to some 60,000 persons connected with the Harvester Organization.

Mr. John E. Rahn, Quality Control Department, Farmall Works, Rock Island, Illinois, assisted on the instructional staff for the ten day course. Mr. A. C. Richmond also assisted on the instructional staff and served as general chairman for both the two day and ten day programs.

Mr. H. A. Weissbrodt, Works Manager, Fort Wayne, Indiana, was a guest speaker at the ten day course. He gave an interesting talk on several successful applications of statistical quality control at the International Harvester Motor Truck Works located at Fort Wayne.

Some Useful Statistical Methods

CALVIN J. KIRCHEN
REMINGTON ARMS COMPANY, BRIDGEPORT, CONN.

The author wishes to acknowledge his indebtedness, for the opportunity to publish the charts accompanying this article, to Dr. R. E. Evans, Manager, Ammunition Division, Technical Department, Remington Arms Company, who devised them, and to the author's employer, the Remington Arms Company. The author also wishes to thank Professor Paul Peach, Institute of Statistics, University of North Carolina, Raleigh,North Carolina, for permission to make use of material concerning the Poisson distribution which he issued in a note several years ago.

The material given below is based upon lectures which the author has given at some of the quality control conferences held by the Federal Products Corp., Providence, R. I. The material was designed to be presented in procedural form rather than in expository form, and this is maintained here, with the express approval of the referee, who felt the procedural form permitted a conciseness not possible otherwise. There are two main sections, the first dealing with applications of the Poisson distribution in obtaining approximate, but satisfactory, solutions of sampling inspection problems, and the second showing applications of the chi-square distribution in comparing samples, the items of which have been classified as being good or defective.

1. Applications of the Poisson Distribution

Six sampling problems and the calculation of the operating characteristic of a sampling scheme (efficiency of a sample size and allowable number of defects in accepting good material and rejecting bad material) will be illustrated by the use of tables and a chart of the Poisson distribution. It is recommended that the reader have one or more of the following at hand: Molina, E.C. "Poisson's Exponential Binominal Limit," D. Van Nostrand Co., Inc., New York, 1943; Table G in E. L. Grant's "Statistical Quality Control," McGraw-Hill Book Co., Inc., New York, 1946; and Fig. 6 in Dodge and Romig's "Sampling Inspection Tables," John Wiley and Sons, Inc., New York, 1944.

A. A lot is known to be 0.8% defective. What is the probability that a random sample of 300 will contain not more than 4 defectives (i.e., 0 or 1 or 2 or 3 or 4)?

1. Molina's II: $pn = .008(300) = 2.4$; find $a = 2.4$ in II. Allowable defectives $= 4$; find $c = 4 + 1 = 5$; table entry $= .0959$; required probability $= 1.0000 - .0959 = .9041$.
2. Grant's G: Find c' or $np' = 2.4$, $c = 4$, read $P = .904$ directly.
3. Fig. 6, D-R: Find $pn = 2.4$ on horizontal base scale; run up vertical to curve $c = 4$; run horizontally to left hand vertical scale and read $P = .905$.

B. Same conditions as before. What is the probability that the sample of 300 will contain **exactly** 4 defectives?

1. Molina's I: $pn = 2.4$ (as before) so $a = 2.4$; find $x = 4$; table entry is .1254.
2. Grant's G: $c' = 2.4$, $c = 3$, $P = .779$; required probability $= .904 - .779 = .125$.
3. Fig. 6, D-R; $pn = 2.4$, $c = 3$, $P = .78$; required probability $= .905 - .78 = .125$.

C. Same conditions as before. What is the probability that the number of defectives will **exceed** 4?

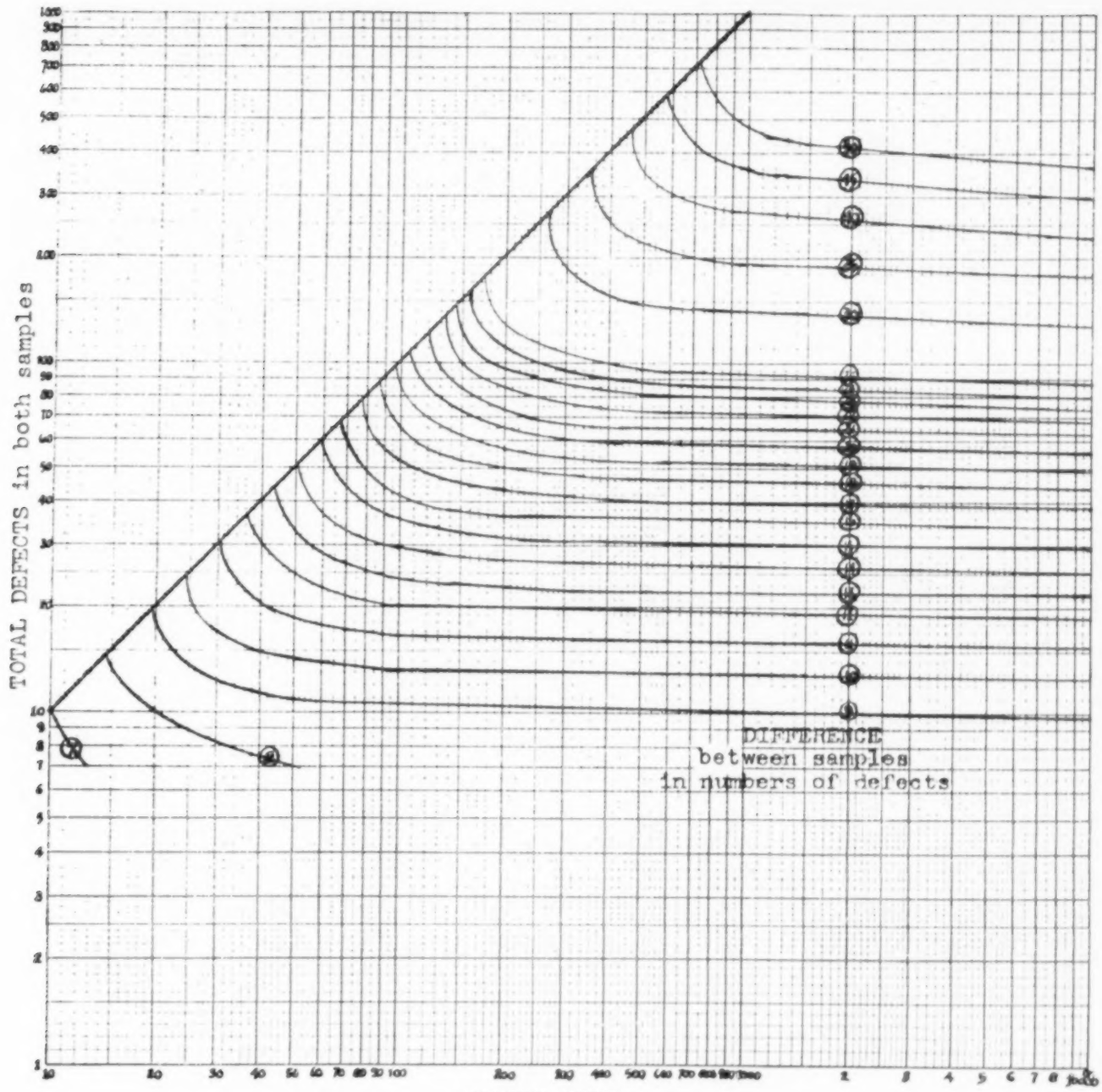
By whatever table or chart used before, the probability of not more than 4 defectives was .9041; the case of exceeding 4 defectives is the mutually exclusive possibility, so its probability is $1.0000 - .9041 = .0959$. This is the probability given directly in Molina's II for $a = 2.4$; $c = 4 + 1 = 5$.

D. A customer's inspection system is that of taking a sample of 1000 and permitting 2 defectives. What is the worst average quality that can be continuously supplied by the vendor with the risk that not more than 1 lot in 50 shall be rejected?

1. Molina's II: $P = 1/50 = .02$, $c = 2 + 1 = 3$. In Table II look along $c = 3$ rows for $P = .02$; closest values found are .014 ($a = .5$) and .023 ($a = .6$). Interpolation for $P = .020$ yields $a = .567$. Then the maximum allowable per cent defective $= (.567)(100)/1000 = .0567\%$.
2. Grant's G: Use $P = 1.00 - .02 = .98$. Go down column headed by $c = 2$ to find values of P nearest to .98: $P = .982$ ($c' = .55$) and $P = .977$ ($c' = .60$). By interpolation for $P = .98$, $c' = .57$, so the maximum allowable percent defective is .057%.
3. Fig. 6, D-R: Find $P = 1.00 - .02 = .98$ on left hand vertical scale. Run a horizontal line to $c = 2$. Drop vertically to base line and read $pn = .56$. Then the maximum allowable percent defective $= .056\%$.

E. Same conditions: Solve for a 50-50 chance of acceptance.

1. Molina's II: $P = .50$ on $c = 3$ lies between $a = 2.6$ and 2.7. Interpolating, $a = 2.69$. Then .269% defective lots will be rejected 50% of the time.
2. Grant's G: Run down $c = 2$ column to P nearest to .50, interpolating between $P = .518$ and .469 to get $c' = 2.67$; so .267% defective lots will be rejected 50% of the time.
3. Fig. 6, D-R: Find $P = .50$ on left vertical scale; run horizontally to $c = 2$; run down vertically to $pn = 2.67$. Then .267% defective material will be rejected 50% of the time.

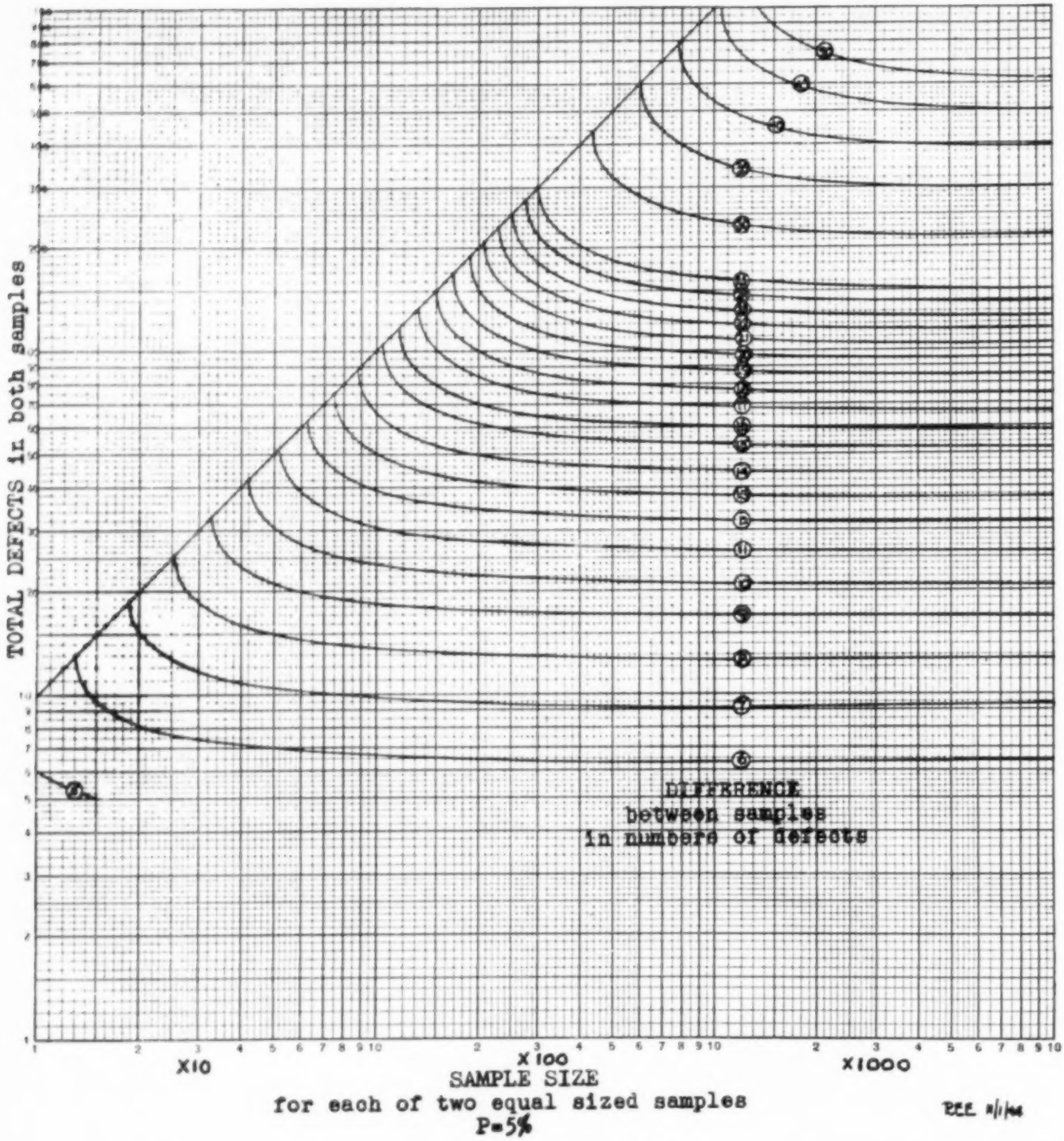


F. Same conditions: What are the chances of acceptance of lots whose fraction defective is .2% (same as worst acceptable sample)?

1. Molina's II: a = pn = 2.0. In row c = 3 for a = 2.0, p = .3233. Required probability = 1.0000 — .3233 = .6767. That is, if lot quality merely equals required sample quality, the lot has only 2 chances in 3 of being accepted!
2. Grant's G: c' = 2.0; c = 2; P = .677 directly.
3. Fig. 6, D-R: pn = 2.0, c = 2 leads on left-hand probability scale to .67 probability of acceptance.

G. Calculation of the Operating Characteristic Curve for a given single sampling plan.

1. Let N (lot size) = 1000, n (sample size) = 50, c (allowable defectives in sample) = 3, lfd = lot fraction defective.
2. Calculating the Operating Characteristic Curve for this single sampling plan means this: for various lot fraction defectives, what are the respective probabilities of accepting a lot of 1000 if a



sample of 50 is taken and 3 defectives are permitted?

4. Plot these various probabilities against the corresponding lot fraction defectives. The resulting curve is called the Operating Characteristic of the single sampling plan. It shows very readily what percent of the time a lot of given fraction defective can be expected to be accepted by the sampling scheme.

3. a. lfd = 0, P = 1: sample must be perfect if the lot is.
   b. lfd = .01. Grant's G: c' = .5, c = 3, P = .998.
   c. lfd = .02. Grant's G: c' = 1.0, c = 3, P = .981.
   d. lfd = .03. Grant's G: c' = 1.5, c = 3, P = .934.
   e. lfd = .04. Grant's G: c' = 2.0, c = 3, P = .857.
   f. lfd = .06. Grant's G: c' = 3.0, c = 3, P = .647.
   g. lfd = .08. Grant's G: c' = 4.0, c = 3, P = .433.
   h. lfd = .10. Grant's G: c' = 5.0, c = 3, P = .265.
   i. lfd = .12. Grant's G: c' = 6.0, c = 3, P = .151.

II. Applications of Chi-Square Tests

The remainder of this material constitutes the second main section referred to earlier. It uses charts

and a formula to provide means of determining whether two samples differ significantly with respect to their numbers of defective pieces.

A. Equal Sample Sizes—Solution by the Chart of Chi-Square.

1. Select the desired risk of error (5% or 1%) and use the corresponding chart reproduced below.
2. Locate the total number of defectives in the two samples on the left-hand vertical scale.
3. Trace horizontally to the point on the vertical line corresponding to the size of the equal samples.
4. If the point thus located lies **on** the curved line giving the difference between the numbers of defectives in the two samples, then the odds are (95 or 99) to 1 that the samples differ significantly. If the located point lies **below** the curved line, the odds are even greater that the samples are significantly different.
5. If the located point lies **above** the curved line corresponding to the difference between the samples, the samples are not significantly different.
6. Example: Assume we have two samples of 250 each, with 10 defectives in one sample, 2 in the other, for a total of 12 and a difference of 8. If we are satisfied with a 95 to 5 risk, choose the chart P = 5%. Find 12 on the left hand vertical scale, trace horizontally to the right to sample size 250. The point thus located lies below the curved line for a difference of 8 defectives between the two samples, so we conclude the sample of 250 with only 2 defectives is better than the one with 10 defectives, and our chances of being wrong are 5 in 100. The P = 1% chart is handled similarly.

TABLE I

	Acceptable	Defective	Totals
Sample 1	a	b	a + b
Sample 2	c	d	c + d
Totals	a + c	b + d	N

Compute: $\dfrac{(ad - bc - N/2)^2 N}{(a+c)(b+d)(a+b)(c+d)}$.

TABLE II

	Acceptable	Defective	Totals
Sample 1	55	5	60
Sample 2	76	14	90
Totals	131	19	150

$$\frac{(55\times14 - 76\times5 - 75)^2 150}{131\times19\times60\times90} = 1.11.$$

B. Unequal Sample Sizes—Solution by Chi-Square Formula.

1. Summarize Samples as in Table I.
   If the computed value is not less than one of the following standards, the difference between the samples is significant at the corresponding risk level:

Risk Level	5%	1%
Standard	3.84	6.64

   These are values of chi-square for one "degree of freedom".
2. Example: Suppose samples of 60 and 90 pieces from two different processes for a product yield, respectively, 5 and 14 defective pieces. Does the sample of 90 with 14 defective pieces indicate that the process which produced it is not as good as the other? (See Table II.)
   The computed number, 1.11, is less than the standard at even the 5% level (3.84), so there is no evidence, on the basis of this test, that the second sample differs significantly from the first.
3. Note: The term N/2 in the formula for chi-square is known as Yates' Correction for Continuity. It is not always included in formulas pertaining to this application. The reader who is interested in acquainting himself with the reasons for using the correction is referred to R. A. Fisher, **Statistical Methods for Research Workers**, 1941, Oliver and Boyd, Edinburgh. This correction was used in devising the chart used in the case of equal sample sizes.

Modern Quality Control

One of the interesting features of the Convention Dinner of the American Society at the Hotel Sherman in Chicago on 5 June of this year was a "first-night" showing of the Johns-Manville Corporation's new color sound picture entitled "Modern Quality Control."

The film was prepared by Johns-Manville for use in instructing its own people in the principles and value of quality control. Mr. R. E. Wareham, Executive Secretary of the American Society, suggested to President Edwards the possibility of securing the film for the dinner meeting. Acting on this suggestion, Mr. Edwards invited Mr. S. Collier, Director of Quality Control of Johns-Manville, to be present at the dinner and to present the picture to the members of the Society.

Mr. Collier graciously consented to do this, and the Society is most

grateful to Mr. Collier and to the Johns-Manville Corporation for affording so many of its members this opportunity of viewing the picture.

Mr. Collier prefaced the showing of the film with a few well-chosen remarks, which Industrial Quality Control is pleased to quote:

"The use of statistics is not new. There never has been a time when scientists and technical men have not unconsciously used some statistical principles in the drawing of conclusions from accumulated data. Unfortunately, many of these conclusions have been based on intuition and thus have not always been in harmony with the true facts. We will admit, in the light of our present knowledge, that in past years many of our own conclusions were educated guesses. However, we do feel that a step forward was made when we began to use frequency data in establishing specification limits for our various products.

"About five years ago, we started to apply some of the principles set forth by Dr. Shewhart and his colleagues. We soon realized some of the deficiencies of our past thinking, and it was immediately apparent that there was need of acceptance of these principles by our production managers, supervisors, industrial engineers, and inspection personnel.

"The education of our inspection group was started at once through the medium of literature and courses of our own design, as well as courses sponsored by the War Production Board and local colleges. However, educating production men in these ideas was quite a different problem. In our contacts with representatives of other companies, we found that they too, had similar problems. After considering the various types of approach, we felt that perhaps a motion picture with a suitable narrative would be most effective. Our reason for this approach was that, in cooperation with the training division, we had recently made a film on quality for a specific product, where the rejects were running high. This film illustrated the various types of rejects, and portrayed each cause. The film had been shown to all the employees from sweeper to factory manager, with appropriate commentary by the training and quality control supervisors. The picture brought home to each employee the importance of his job in maintaining quality. We have always worked on the fundamental theory that if we instill **pride of workmanship** in our men, our problems of quality and inspection become relatively simple.

"The effect of that earlier picture was immediate, and rejects dropped to less than 1/3 the previous level. The picture had put across our ideas, and it made a distinct impression on everyone in the production group. For this reason we felt that a similar training film would be one of the best means of presenting modern quality control to our production men.

"We made inquiries as to the availability of motion pictures on statistical quality control, but were unable to find a film suitable for our problems. In collaboration with our Training Division, we then decided to make our own movie, patterned around our own products and problems. The objective was to sell statistical quality control to production and industrial engineering groups, citing varied applications and case histories in the field of our own operations. The film was meant only for home consumption and is not an advertising medium. We have taken a few minor liberties with some of the statistical theories, but we believe that the advantages to be gained warrant such liberties.

"We have been working on this motion picture for some time, and its completion has been possible only because of the unstinting efforts of Miss Gertrude Mothersele, Messrs. W. H. Graham, P. B. Proctor, and E. F. Smith of our Quality Control Department, Mr. Ralph Hartwig, Training Coordinator of our Industrial Relations Department, Mr. Luther Reed, Manager of our Motion Picture Section, and Mr. E. A. Reynolds, formerly of Johns-Manville. We are also grateful to Mr. Ralph Wareham of the Society for his technical assistance.

"This film was returned to us from the laboratories only last week, and we have not yet shown it even to our own production people. We are pleased to have the opportunity of making its initial showing to the American Society for Quality Control."

STATISTICAL CONTROL RESEARCH AND TRAINING PROGRAM, SYRACUSE UNIVERSITY AND SYRACUSE SECTION OF A.S.Q.C.

Syracuse University has announced a comprehensive program in industrial quality control research and training under the sponsorship of the United States Department of Commerce and in cooperation with the Syracuse Section of the A.S.Q.C. and industry in the Syracuse area. The project is designed to aid local industry through inspector training and in-plant aid in the application of statistical quality control methods, and also to investigate the present use of these methods in representative industries and to study the results of such cooperative training programs.

The tentative plans for the project include investigation of the quality control methods of industries of varying sizes and type of operations to determine the extent of use of statistical methods, the industrial desire for additional training at this time, and the possibility for increased application of statistical quality control. In addition, the project will include free training courses for industrial employees and in-plant cooperation with local inspection personnel for the application of these methods to specific production problems.

The University has engaged Mr. Edward A. Reynolds to work in association with Professor Washington Platt of the University's Administrative Engineering Department in directing this project. Mr. Reynolds was formerly in charge of statistical quality control methods for Johns-Manville's United States and Canadian factories, and more recently, inspection manager for the Easy Washing Machine Corporation. It is expected that the detailed plans will be reviewed with local and nationally known leaders in the field of quality control, and it is the hope of both the University and the Syracuse Section of A.S.Q.C. to make this project of benefit nationally as well as locally.

ANNUAL REPORTS

At the Annual Meeting of the Society in New York on 27 June, 1947, the President, the Executive Secretary, and the Treasurer presented Annual Reports on behalf of the Board of Directors. These reports were duly accepted, ordered extended to include the balance of the fiscal year, and ordered published in the September issue of Industrial Quality Control, under the provisions of Sections **29.c** (3), **29.d.** (5) and **33.h.** of the Constitution. The reports follow.

REPORT OF BOARD OF DIRECTORS

THE BOARD OF DIRECTORS of the American Society for Quality Control, Incorporated, presents herewith to the membership its first annual report, for the period from 16 February, 1946 through the end of the fiscal year on 30 June, 1947. The report includes a brief summary of the principal activities of the Society during the period covered, more detailed information having been given to the membership in the several issues of Industrial Quality Control which have been published during the period. Appended to this report are the reports of the Executive Secretary and of the Treasurer setting forth respectively, the status of the membership roll and of the roll of Sections, and the financial condition of the Society, as of the close of the fiscal period. The Auditing Committee's certification of the Treasurer's report is also appended.

Board of Directors' Meetings

Only one formal meeting of the Board was held during the period in question,—in Chicago on 5 June, 1947. The proceedings of this meeting were recorded in some detail in the July, 1947 issue of Industrial Quality Control, and will not be repeated here. Important actions included confirmation of the President's appointment of Professor Mason E. Wescott to succeed Dr. Martin A. Brumbaugh as Chairman of the Editorial Board, election of Dr. Walter A. Shewhart as the first Honorary Member of the Society, completion of the necessary authorizations for the setting up and functioning of the Shewhart Medal Foundation, and unanimous endorsement of the proposed new constitution for the Society as submitted to the membership for action.

Two informal meetings of the Board were also held during the period, — in Chicago on 5 March, 1946, and in New York on 27 January, 1947. No quorum was present at either of these informal meetings. The first was given over to general discussion of Society activities and plans, while the second was devoted entirely to consideration of suggested provisions in the proposed new constitution.

Executive Committee Meetings

Nine meetings of the Executive Committee were held during the fiscal period in question, as follows:

Chicago, 5 March, 1946
New York, 22 May, 1946
Buffalo, 28 September, 1946
New York, 14 December, 1946
New York, 15 December, 1946
Rochester, 17 February, 1947
New York, 26 April, 1947
New York, 27 April, 1947
New York, 27 June, 1947.

All except the New York meeting on 14 December and the Rochester meeting on 17 February were formal meetings with a full quorum present. The 14 December and 26 April meetings were devoted exclusively to consideration of suggested provisions in the proposed new constitution. All of the other meetings were given over to general discussions and decisions with respect to Society activities and plans. The proceedings of these meetings have largely been reported in succeeding issues of Industrial Quality Control, and will not be repeated here.

Sections Visited by President Edwards

New England Region
- Boston
- Western Massachusetts
- Hartford
- Southern Connecticut

Middle Atlantic Region
- Metropolitan
- Delaware

Northern Region
- Buffalo
- Rochester
- Southern Tier
- Michigan

Central Region
- Ohio

Mid-West Region
- Chicago
- Iowa

In addition to speaking at meetings of most of the above Sections, the President also spoke at the Mid-West Regional Meeting in Chicago and the Middle Atlantic Regional Meeting in Princeton, N. J., both in 1946, as well as the National Convention of the Society in Chicago in 1947.

Annual Meeting

The annual business meeting of the Society was held in New York City on 27 June, 1947. The proceedings of the Annual Meeting were recorded in some detail in the July, 1947 issue of Industrial Quality Control and will not be repeated here. The annual report of the Board of Directors was presented by President Edwards; the status of the membership roll and of the roll of Sections was outlined by Executive Secretary Wareham; and the Society's financial condition was summarized by Treasurer Davis. The report of the judges of election was presented, and those officers-elect present responded with brief expressions of appreciation for the honor conferred upon them. The new constitution of the Society was declared adopted and its provisions effective as of 1 July, 1947.

National Convention

The first Convention of the Society was held in Chicago on the 5th and 6th June, 1947 in conjunction with the second Regional Meeting of the Mid-West Sections. The Convention was reported in some detail in the July, 1947 issue of Industrial Quality Control and no detailed report will be given here. Its outstanding success was due largely to the devotion and hard work of the Mid-West Region Members and Committees who played host to the Society.

Regional Meetings

Four large Regional Meetings were held during the period:

Mid-West
Chicago 5 and 6 March, 1946
New England
Boston 15 November, 1946
Middle Atlantic
Princeton, N. J. 14 December, 1946
Mid-West
Chicago 5 and 6 June, 1947

Each of these meetings was sponsored by all of the American Society Sections in its Region. In addition to luncheon and dinner sessions of a more general character, each meeting included a number of "clinical" sessions devoted to exposition of specific phases or applications of quality control. All four meetings were highly successful and contributed substantially to an increase in quality control enthusiasm in their respective Regions.

Section Meetings

All of the Society's twenty-five Sections held well-attended meetings more or less regularly during the period. Technical sessions were frequently preceded by a less formal dinner session. Two of the Sections also held all day meetings with "clinical" sessions as follows:

Rochester
Rochester 19 February,1946
Michigan
Detroit 7 June, 1946
Rochester
Rochester 18 February, 1947
Michigan
Detroit 20 June, 1947

Section meetings constitute a substantial and important contribution to the life of the Society and to the gain which accrues to individual members from the Society. It is to be hoped that these Section activities will increase in scope and strength with the continuing growth of the national organization.

Advisory Council

With the approval of the Executive Committee, the President appointed the following to the Advisory Council of the Society:

Dr. E. U. Condon
Director, Bureau of Standards,
United States Department of Commerce
Washington, D. C.

Mr. M. Herbert Eisenhart
President, Bausch and Lomb Optical Co.
Rochester, New York
Brigadier General Hermon F. Safford
Executive Vice-President
Ohio Rubber Company
Willoughby, Ohio
Dr. Walter A. Shewhart
Member of Technical Staff
Bell Telephone Laboratories, Inc.
Murray Hill, New Jersey
Mr. Charles D. Wiman
President, Deere and Company
Chicago, Illinois

All of these gentlemen have graciously accepted appointment, and the Society is most fortunate in being able to call upon them for advice and counsel in important matters of policy or procedure.

Industrial Quality Control

The Society has been fortunate in persuading an extremely able and well-balanced group of men to accept membership on its Editorial Board. Under the able Chairmanship of Dr. Martin Brumbaugh, this Board has maintained and even improved the high standard he had already established as Editor of Industrial Quality Control. The content of the magazine has been increased from 20 pages per issue to 32 pages — seven of the eight issues published during the period covered by this report having been of the 32-page content.

During this same period, the circulation of the magazine has quadrupled — the present circulation being approximately 2,200. Several articles have been reprinted from the magazine for individual distribution. That many of the articles are of more than passing worth is attested by the very substantial demand for back issues. This demand has necessitated reprinting two of the earlier issues, and it appears possible that reprinting of some further issues will be necessary.

With the object of increasing the advertising income from the magazine, the Society signed a contract at the beginning of 1947 appointing exclusive Advertising Sales Representatives. This contract has been terminated effective as of July, 1947.

The Society has suffered a real loss in the resignation of Dr. Brumbaugh as Chairman of the Editorial Board effective 1 July, 1947. It has been most fortunate in securing the consent of Professor Mason Wescott to succeed Dr. Brumbaugh as Chairman.

The first issue of the News Supplement to Industrial Quality Control appeared on 1 June, 1947. This will contain news of Section, Regional and National Meetings, past and to come, announcements of Educational Courses to be given, personal news items, etc. The Supplement is being edited by Mr. Ernest H. Robinson of Chicago, and the Society is most fortunate in having him consent to undertake the work. The Supplement will, of course, be mailed to all members.

Standing Committees

The Committee on Professional Ethics and Qualifications completed during the period a structure for grades of membership, and qualification requirements covering each grade, which have been included in the Society's new Constitution. This Committee has also made substantial progress in the drafting of a Code of Ethics for the Society, and in the working out of an acceptable procedure under which personal and professional advertising notices may be placed in Industrial Quality Control by members.

Early in 1947, the Committee on Constitution and By-Laws placed in the hands of the Executive Secretary a petition for amendment of the Constitution and By-Laws so that the President and Vice-President of the Society could be re-elected to a second term if this should prove desirable. The Executive Secretary mailed 1,698 ballots to members eligible to vote on adoption of this amendment. Of these, 1,099 valid ballots were returned—1,046 favoring the amendment and 53 opposing. The amendment was hence adopted by the favorable vote of more than 95% of the members voting.

The principal effort of the Constitution and By-Laws Committee was devoted to the drafting of an entire new Constitution for the Society. After almost continuous work in this connection from early September, 1946 through late April, 1947, this Committee submitted to

the Executive Secretary its final draft of the new Constitution. Unanimously endorsed by this Committee, by the Committee on Professional Ethics and Qualifications, by the Executive Committee, and subsequently by the Board of Directors, the new Constitution was submitted to the membership for action in the postal ballot in June, and was adopted by the affirmative vote of more than 94% of the members voting.

After careful canvas of its problem, the Nominating Committee submitted to the Executive Secretary the following nominations for officers for the fiscal year 1947-48:

For President
George D. Edwards

For Vice-President
Frederick J. Halton, Jr.

For Executive Secretary
Ralph E. Wareham

For Treasurer
Alfred L. Davis

In the postal ballot terminating at the Annual Meeting, the above nominees were all elected by large majorities.

The Auditing Committee conducted its scrutiny of the books and records of the Treasurer with meticulous care, and the results of its work are set forth in its certification appended to the Annual Report of the Treasurer.

General Committees

While the Committee on Membership was unable to carry out during the period any full-fledged membership campaign on a national scale, some progress was made in formulating plans along these lines. The Committee has also made a number of suggestions calculated to facilitate membership work, and plans are under way for giving effect to these. Important among them is a suggestion that a uniform membership application blank be used exclusively by all Sections and by the American Society.

The Committee on Programs and Speakers has not been called upon to any extent so far for aid in suggesting speakers or in arranging programs. It is attempting to formulate a list of representative speakers on a variety of subjects, who would consent, when possible, to address Section, Regional or National meetings. The Committee has also considered carefully the working of the program at the June, 1947 Convention of the Society, and has formulated a set of recommendations for the consideration of Committees undertaking the program-planning of future Conventions.

The Committee on Publicity and Public Relations has continued, throughout the period, discreet efforts to secure publicity of the right sort both for quality control in general and for the American Society in particular. Articles describing the advantages of quality control as reported at Section and Regional meetings of the Society, and at the Society's Convention, have appeared in a number of the better-known technical and business magazines having national circulation. Favorable notices regarding the Society have also appeared in the journals of several of the larger national engineering societies, and in a considerable number of newspapers both local and of wider circulation.

The Committee on Relations With Educational Institutions has made important progress in laying the ground-work for a sound program for its activities. It submits the following suggestions to the Sections and to the individual members of the Society:

1. That they secure attendance of college and university teachers at Society meetings and encourage their active interest in the Society and its activities.
2. That they provide speakers for local meetings of the American Society for Engineering Education, and that A.S.Q.C. do likewise for the higher echelons.
3. That they encourage in every way possible the provision of summer employment in industry for teachers of quality control.
4. That they review carefully their membership representation on the Committee, and present new nominations where this appears desirable.

In the course of its work, this Committee has found it desirable to constitute a Sub-Committee on College courses, which has given considerable study to the matter of under-graduate and graduate instruction in statistics and quality control. As a result of this study, the Sub-Committee has submitted the following tentative conclusions:

1. Basic statistics is fundamental to all branches of engineering endeavor, and should be required in all undergraduate curricula.
2. Such a basic statistics course should consist of a year's work (6 credit hours) embracing frequency distribution and measurements, linear correlation, multiple correlation, introduction to tests for significance, control charts for variables and attributes, probability, sampling, application to tolerances and specifications, etc.
3. Pressure for highly specialized courses in quality control or industrial statistics for undergraduate engineering students should be resisted.
4. Advanced study in correlation, tests of significance, etc., as well as in analysis of variance, design of experiment, etc., should not be required of all engineers, but rather should be presented as electives for undergraduates or be postponed to the graduate level.

The Main Committee on Relations with Educational Institutions has given its tentative endorsement to these conclusions of its Sub-Committee. It invites members and non-members to submit factual information on present practice and future development of college courses along these lines, and to send in information, comments, and questions relating to the subject which will be helpful to the Committee in forwarding its study and crystallizing its conclusions.

The Committee on Relations with Other Technical Societies has formulated and adopted a statement of its objectives, together with statements of the duties of individual members of the Committee and of its Regional Chairmen. It has formally recommended that each Section of the Society affiliate with the Engineering Council or similar group in its area, where such a Council or group exists. Where no such Council or group exists, the Committee has recommended that

the Section take the initiative in organizing one. The Committee has noted that letters have been sent, by several Sections of the Society, to sections or local chapters of other technical societies in their several areas, listing pertinent information and the names of qualified speakers on quality control who are available. The Committee recommends that other Sections adopt this practice. The Committee urges that Sections invite joint meetings with other technical groups in their several areas, where scheduled topics might prove of mutual interest to the membership involved. It cautions however, that particularly capable speakers should be chosen for such joint meetings, and that the discussion should be kept on a nontechnical level so far as possible. In this connection, the Committee suggests that Sections obtain a list of possible speakers, with some statement of their past success, from the Committee on Programs and Speakers. The Committee on Relations with Other Technical Societies concludes its recommendations by urging that the above procedures be followed similarly, so far as appropriate, by its Chairmen at Regional and National levels.

Appreciation

To the ASQC Committees, to the Regional and Executive Chairmen of those Committees, to Section officers, and to the members in general, the Board of Directors expresses its deep appreciation for the loyal and effective effort which all have devoted to the advancement of the Society, and the Board extends its thanks for the splendid cooperation and support which it has uniformly received.

For the Board of Directors
GEORGE D. EDWARDS,
President.

REPORT OF EXECUTIVE SECRETARY

The organization meeting of the Society was held at the Edison Electric Institute, New York City, on February 16, 1946. At that meeting representatives were present from the following seventeen local quality control societies: Boston, Buffalo, Chicago, Delaware, Detroit, Georgia, Illinois, Indiana, Iowa, Metropolitan, Milwaukee, Northwestern, Ohio, Philadelphia, Pittsburgh, Rochester and Syracuse. The total local membership of these seventeen sections was then 1,186 as shown in Exhibit A.

Since the organization meeting, two of the original local societies have combined into a single Section of the American Society. Chicago and Northwestern became the Chicago Section. The following new Sections have joined the American Society in the order listed: California, Omaha, St. Louis, Western Massachusetts, Hartford, Northeastern Indiana, Southern Tier, Southern Connecticut, and Toronto. Thus, there are now 24 Sections of the Society in the United States and one in Canada.

The attached Exhibit A shows the membership of the Society by Region and by Section, indicating the number of Founding Members and the total membership of each Section. The Chicago Section (with 198 members) is now the largest Section in the Society; the Metropolitan Section has the largest number of Founding Members (48); the New England Region has the greatest number of new Sections (3); the Central Region has had the largest relative growth during the period, more than doubling its original membership.

Growth in membership of the Society during the period is shown by the following record of Regular and Founding Members:

Date	Founding	Regular	Total
May 22, 1946	91	408	499
September 28, 1946	139	891	1030
December 15, 1946	148	1292	1440
April 1, 1947	184	1606	1790
June 5, 1947	188	1633	1821
June 30, 1947	243	1683	1926

The steady and uninterrupted growth of the Society has been most encouraging throughout the period since its inception. As of the end of the year, groundwork was being laid for a number of new Sections.

Respectfully submitted
RALPH E. WAREHAM,
Executive Secretary.

REPORT OF TREASURER

Appended hereto are Balance Sheet of the Society as of 30 June, 1947 (Exhibit B), and Statement of Receipts and Disbursements of the Society for the period from 16 February, 1946, to 30 June, 1947, inclusive (Exhibit C).

Respectfully submitted
ALFRED L. DAVIS,
Treasurer.

CERTIFICATION BY AUDITING COMMITTEE

We have examined the Balance Sheet of the American Society for Quality Control, Inc., as of June 30, 1947, and the Treasurer's Statement of Receipts and Disbursements for the period February 16, 1946, to June 30, 1947, inclusive. Without making a detailed audit of the transactions, we tested samples of the records of cash receipts and disbursements to the extent we deemed appropriate. The amount of cash on hand was verified with the bank of deposit. The methods of arriving at the estimates shown on the balance sheet were reviewed with the Treasurer.

In our opinion, the accompanying Balance Sheet and Statement of Receipts and Disbursements fairly presents the financial position of the American Society for Quality Control, Inc. as of June 30, 1947, and the Treasurer's operations during the period February 16, 1946 to June 30, 1947.

HOWARD L. JONES, Chairman
HOWARD L. BOLTON
G. RUPERT GAUSE
PAUL A. ROBERT
JOSEPH SADOWSKI

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EXHIBIT A

American Society for Quality Control, Inc.
Report on Membership as of June 30, 1947

	Local Membership at Time of Organization	Founding	Present Membership Regular	Total
New England Region				
Boston	91	15	109	124
Hartford	....	....	36	36
Southern Connecticut	....	1	46	47
Western Massachusetts	....	1	17	18
Total	91	17	208	225
Northern Region				
Buffalo	108	8	105	113
Michigan	91	8	92	100
Rochester	163	17	103	120
Southern Tier	....	1	59	60
Syracuse	35	4	64	68
Toronto	....	5	23	28
Total	397	43	446	489
Middle Atlantic Region				
Delaware	44	6	36	42
Metropolitan	170	48	112	160
Philadelphia	55	15	83	98
Total	269	69	231	300
Central Region				
Georgia	9	6	25	31
Ohio	31	13	85	98
Pittsburgh	37	4	58	62
Total	77	23	168	191
Midwestern Region				
Chicago	143	18	180	198
Illinois	42	1	41	42
Indiana	36	5	36	41
Iowa	81	14	74	88
Milwaukee	50	5	66	71
N. E. Indiana	....	3	40	43
Omaha	....	1	6	7
St. Louis	....	7	42	49
Total	352	54	485	539
Western Region				
California	....	11	56	67
At Large	....	26	89	115
Grand Totals	1186	243	1683	1926

EXHIBIT B

AMERICAN SOCIETY FOR QUALITY CONTROL, INC.
Balance Sheet — June 30, 1947

Assets		**$3,719.50**
Cash		$3,085.25
Accounts Receivable		538.25
Sales of back issues	$163.25	
Library Subscriptions	45.00	
Advertising	330.00	
Back Issues and Reprints		1.00
Stationery on hand		95.00
Liabilities		**$2,016.18**
Publication of Year Book (estimated cost)		$1,000.00
Unpaid Advertising Commissions		175.00
Unpaid Secretarial Services		86.94
Unpaid Withholding Tax		25.50
Unpaid Office Expenses		11.29
Portion of Membership Dues Refundable to Local Sections		8.00
Membership Dues Paid in Advance		486.50
Unearned Portion of Library Subscriptions		222.95
Net Worth		**$1,703.32**

EXHIBIT C
AMERICAN SOCIETY FOR QUALITY CONTROL, INC.
Statement of Receipts and Disbursements
2/16/46 – 6/30/47

Receipts:		
Membership Dues	$5,751.00	
Founding Contributions	1,821.43	
Advertising, I. Q. C.	1,444.91	
Founding Memberships	1,332.27	
Sale of Back Issues, I. Q. C.	1,291.62	
Library Subscriptions, I. Q. C.	986.82	
Miscellaneous	78.50	
Society Credits	38.00	
Membership Dues—Library Subscriptions, '47-'48	486.50	
Total Receipts		$13,231.05
Less Remission of Dues to Sections		433.00
Net Receipts		$12,798.05
Disbursements:		
Magazine:		
Publishing (eight issues)	$4,869.94	
Postage	625.45	
Reprints	494.55	
Mailing (envelopes, labels, etc.)	404.67	
Advertising Commissions	106.50	
Editorial Assistance	105.62	
Office Expense	87.59	
Petty Cash	81.96	
Travel Expense	47.78	
Total		$6,824.06
Executive Secretary:		
Stenographer	$1,161.76	
Printing and Mimeographing	561.03	
Election and Ballot Expense	391.27	
Postage	235.00	
Office Supplies	72.10	
Promotion	10.98	
Total		$2,432.14
President:		
Postage	$ 165.77	
Incorporation Certificate	42.95	
Telephone and Telegrams	35.30	
Stenographer	25.00	
Miscellaneous	21.70	
Total		$ 290.72
Treasurer:		
Office Supplies	$ 61.90	
Postage	34.00	
Bond	12.50	
Petty Cash	10.00	
Bank Charges	9.73	
Stenographer	7.50	
Telephone	3.00	
Total		$ 138.63
Sections and Committees:		
Printing	$ 25.75	
Postage	1.50	
Total		$ 27.25
Total Disbursements		$9,712.80
Balance on Hand		**$3,085.25**

AMERICAN SOCIETY NEWS

RE-ENROLLMENT OF 1946-47 MEMBERS FOR 1947-48

Attention of Section officers is called to the fact that their members have encouraged the American Society in the undertaking of continuing operational expense, and that American Society dues are the only source from which this expense can be met. While the Society has accumulated a small amount of working capital during its first year, this is insufficient to carry it through any large proportion of the new year. It must hence look to prompt dues renewals to enable it to continue operations.

Under Section **23. b.** of the new Constitution, it is the duty of each Section of the Society, promptly after 1 July, to render to each of its members affiliated with the American Society a bill covering American Society dues for the ensuing year. Under Section **23. c.** of the Constitution, it is the duty of each Section of the Society to transmit to the Executive Secretary, on or about the first of each calendar month, the aggregate amount received by that Section during the preceding month for dues in the American Society.

While a substantial number of new members have been enrolled for 1947-48, the officers of the American Society have been somewhat disturbed by the slowness with which some of the Sections are re-enrolling their old members in the American Society for 1947-48. As of 15 August, only 10 of the 25 Sections had re-enrolled any of their 1946-47 members for 1947-48. Of the 10 Sections mentioned, Buffalo stood first with 58 re-enrollments (51% of its 1946-47 enrollment). The Ohio Section stood second with 25 re-enrollments (28% of 1946-47), and the Iowa Section stood third with 23 re-enrollments (also 28% of 1946-47). Five of the 10 Sections, however, had re-enrolled only one member each.

It is recognized that the Summer season is not a particularly effective time to attempt re-enrollments, but is hoped that with the advent of Fall, it will be possible to record a substantially better showing in the November issue of the magazine.

TRANSFERS TO SENIOR MEMBERSHIP

The Senior Member grade in the American Society is intended for all those members who are 24 years of age or more and who have been practicing or teaching quality control or inspection for two years or more. Corporate members paying Senior Member dues carry their full share of the cost of maintaining and operating the Society. They hence constitute the back-bone of its strength, because any organization which is weak financially is weak in every way. The vast majority of the present corporate membership of the Society is eligible to the Senior Member grade.

The Member grade in the Society is intended for those younger members who are just getting started in quality control or inspection work, and for whom the higher Senior Member dues would constitute a hardship. While members paying Member grade dues do not carry their full share of the financial burden, the Society carries them as its investment in the profession and because it looks upon them as potential Senior Members who will later be able to undertake their full share of the burden.

With adoption of the new Constitution, all corporate members of the Society were automatically enrolled in the Member grade, and their transfer to the Senior Member grade requires affirmative action individually on their part. During the earlier years of operation of the so-called "escalator clause" (Section **4. d.**) of the Constitution, however, the formalities involved in such transfers are largely being waived and eligible Members may accomplish transfer by merely paying the higher dues involved. Corporate members who have already paid Member grade dues for 1947-48 may accomplish transfer by merely paying the difference in dues either to their Section secretary or to the Executive Secretary of the American Society.

It is hoped that all eligible Members financially able to do so will recognize their responsibility for carrying their fair share of the cost of operating the Society, and will effect their transfer to Senior Membership promptly.

While an important number of such transfers have already been effected, their incidence has been extremely "spotty" Sectionwise. As of 15 August, only five of the Society's 25 Sections had any Senior Members whatever, and three of these had only one Senior Member each. It is perhaps noteworthy in this connection, that three of the four "At Large" renewals received up to that date were for the Senior Member grade.

On the more favorable side of the picture, the officers of the Iowa and Ohio Sections have already carried out a carefully planned effort to secure membership renewals, and to effect as large a number of transfers as possible in the process. The results of this work up to 15 August were as follows:

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Section	No. Transferred To Senior Membership	% Transfers To Total Renewals
Iowa	22	96%
Ohio	22	88%

The experience of these Sections affords ample evidence that real planned effort along these lines can be fruitful, and that the goals aimed at by the American Society are readily attainable.

Officers of all other Sections are urged to make plans along similar lines and to carry them out as early as possible. The officers of the Iowa and Ohio Sections will be glad to advise officers of other Sections, upon request, as to the methods and procedures which have been found most effective along these lines.

WAR DEPARTMENT CERTIFICATE OF APPRECIATION TO PRESIDENT EDWARDS

On 4th September, Lt. Col. Edward Gluck, Chief of the New York Ordnance District, presented to President Edwards the War Department's Certificate of Appreciation "for loyal and outstanding assistance to the Ordnance Department during World War II in the application of quality control to quantity production."

Early in 1942, Mr. Edwards went on loan from Bell Telephone Laboratories to the Ordnance Department, where he became Consultant to the Secretary of War on Quality Control. Under his guidance, acceptance quality control procedures were successfully introduced in connection with a very large proportion of ordnance items. Substantial improvements in quality and very large savings in manpower resulted from this work. In late 1943, he undertook work in connection with similar application of these principles to Signal Corps procurement, and by the War's end a large proportion of Signal Corps purchases was being accepted on a quality control basis with corresponding savings. In 1944, he was placed in charge of an Army Service Forces Headquarters program for training personnel from all of the Technical Services of the Army in the application of acceptance quality control procedures.

This new award to Mr. Edwards from the Secretary of War follows an earlier citation made to him by Lieutenant General Campbell, Chief of Ordnance, in 1944.

ADVERTISING CONTRACT CANCELLED

At its meeting on 27 June, the Executive Committee carefully considered all phases of the problem involved in securing advertising in INDUSTRIAL QUALITY CONTROL. At the conclusion of this consideration, the Committee unanimously directed the President to serve immediate notice of cancellation of the contract then in force with the Advertising Sales Representatives of the magazine.

This step again places the Society, for the present, in the position of accepting advertising directly. Members in a position to secure, or to influence the placing of advertising which would appropriately appear in INDUSTRIAL QUALITY CONTROL, are urged to communicate with the Treasurer or to refer prospective advertisers to him. The usual 15% commission will be allowed to Advertising Agencies, along with a further discount of 2% for payment within 10 days.

Rates and all other information with respect to advertising in INDUSTRIAL QUALITY CONTROL may be secured from Alfred L. Davis, Treasurer, American Society for Quality Control, Inc., c/o Rochester Institute of Technology, Rochester 8, N. Y.

MEMBERSHIP ON THE BOARD OF DIRECTORS

Terms of the Directors representing the Sections listed below having expired, those Sections have chosen new Directors as indicated to represent them on the American Society Board for the term ending 30 June, 1949.

Boston—Warren R. Purcell, Salem, Mass.

California—Wyatt H. Lewis, Ontario, Cal.

Delaware—Wayne A. Kirklin, Wilmington, Del.

Hartford—Stanley G. Johnson, Hartford, Conn.

Indiana—Arthur Bender, Jr., Anderson, Ind.

Metropolitan—Paul S. Olmstead, Murray Hill, N. J.

Michigan — Herbert G . Winter, Wayne, Mich.

Ohio—Wade R. Weaver, Cleveland, Ohio.

Philadelphia—Irwin S. Hoffer, Philadelphia, Pa.

Rochester—Halsey H. Kent, Rochester, N. Y.

Southern Connecticut—Elwood E. Folsom, Jr., Bridgeport, Conn.

Syracuse—Martin A. Brumbaugh, Syracuse, N. Y.

Western Massachusetts—Joseph J. Ferri, Springfield, Mass.

Directors representing the Illinois, Iowa and Pittsburgh Sections have resigned. New Directors to fill the unexpired term ending 30 June, 1948 have been chosen as follows:

Illinois—A. C. Richmond, Chicago, Ill.

Iowa—James M. Ballowe, Skokie, Ill.

The Pittsburgh Section has still to choose its Director for the unexpired term ending 30 June, 1948.

EXECUTIVE COMMITTEE 1947-1948

New Regional Directors having been duly chosen to succeed all of those whose terms have expired or who have resigned, the Executive Committee for 1947-48 is now complete and is constituted as follows:

Chairman:

George D. Edwards, President.

Frederick J. Halton, Jr., Vice-President.

Secretary:

Ralph E. Wareham, Executive Secretary.

Alfred L. Davis, Treasurer.

Mason E. Wescott, Chairman, Editorial Board.

Elwood E. Folsom, Jr., Regional Director, New England.

Irwin S. Hoffer, Regional Director, Middle Atlantic.

Alfred J. Winterhalter, Regional Director, Northern.

Wade R. Weaver, Regional Director, Central.

Arthur Bender, Jr., Regional Director, Mid-West.

Wyatt H. Lewis, Regional Director, Western.

The new Executive Committee held its first meeting in Endicott, New York, on Saturday, 13 September, 1947.

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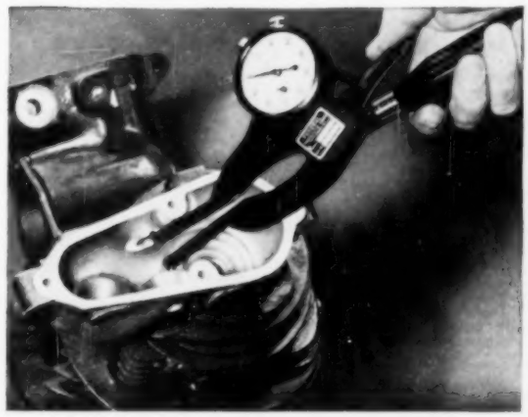

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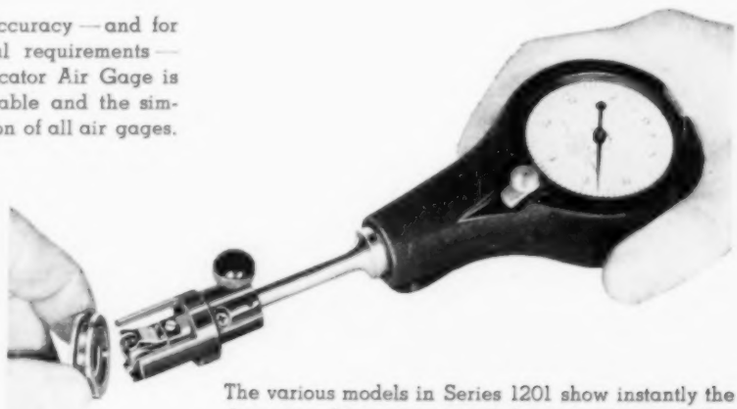

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